THE

# GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. II.

No. VIII.—AUGUST, 1905.

## ORIGINAL ARTICLES.

### I.—The Recent Geological History of the Baltic. Part II: The Ancylus Sea and the Baltic Breach.

By Sir H. H. Howorth, F.R.S., F.G.S.

(PLATE XIX.)

IN the previous paper I ventured to trace the history of the Baltic back to the time when the latest of its raised beaches were laid down, and to show that it was then considerably larger in size, and that its waters were more salt than they are now, although they were even then brackish (see Map I, Pl. XIX).

This conclusion was derived mainly from an examination of the molluscan remains in the more recent shell-beds. It is confirmed by other evidence; thus, Munthe mentions the occurrence in the so-called *Litorina* beds of three species of Rhizopods, whose present and former distribution in the Baltic is shown in the following table:—

| | Present Distribution. | In Litorina Strata. |
|---|---|---|
| *Nonionina depressula* ... ... | Warnemünde ... ... | N.W. of Neder Kalix. |
| *Polystomella striatopunctura* | Warnemünde ... ... | Hernön and Gänsvik. |
| *Rotalina Beccarii*... ... ... | Great Belt and the Sound S. of Hven ... | Åland, Knutsboda, Obbnas, 35 km. S.W. of Helsingfors. |

The specimens of these three species from the *Litorina* deposits seem, says Munthe, to be dwarf forms, and their distribution, like that of the before-mentioned marine organisms, point to different hydrographic conditions from the present (Geol. Inst. Upsala, vol. ii, p. 36).

Our present ignorance of the distribution of the Ostracoda in the Eastern Baltic prevents our making the same minute induction in regard to them, but Munthe says that in general the fossil Ostracodan fauna also points to different hydrographical conditions from the present (id., p. 38).

In regard to the marine diatoms and their distribution there is more than one ambiguity. Munthe has, however, concluded from a minute examination of the problem that they point to a greater saltness in the *Litorina* sea than in the Baltic nowadays, and he adds that an investigation of certain recent samples taken from the South Baltic and adjacent regions proves that the diatomaceous flora of the *Litorina* sea has roughly its closest parallel nowadays in about the same region as its molluscan fauna (id., p. 32).

Having defined the extent and condition of the Eastern Baltic in the so-called *Litorina* time, we will now try and carry the story a little further. The older inquirers, and notably Lovén and Erdmann, argued that the *Litorina* sea was the direct continuation *in situ* of an older so-called ice sea, which was marked by the presence of *Yoldias* and other northern shells.

This was a mere speculation, however, since nowhere had a deposit been found showing a graduation or change from one set of conditions to the other, nor had any traces of the so-called *Yoldia* beds been found over a very large part of the area where the former presence of the *Litorina* sea was well established.

In 1887 Munthe published a very important paper condensing the results of his inquiries in the island of Gotland. In this paper he first definitely showed that the views of Lovén and the older investigators of the history of the Baltic could no longer be maintained. He proved, in fact, that instead of the *Litorina* sea being a direct successor of the so-called *Yoldia* or ice sea it was preceded over a large part, if not all the Baltic area, by a condition of things in which the Baltic formed a large fresh-water lake. To use his own words, "it became evident that the *Litorina* fauna was a completely distinct fauna and immigrated to the Baltic comparatively late, and could scarcely be supposed to have entered by any other route than that of the Sound and the Belts." The importance of this conclusion justifies me in giving its history in some detail.

The first step in defining the problem was taken by Schmidt in an addition to G. von Helmersen's memoir on the diluvial beds of Russia, published in the Memoirs of the St. Petersburg Academy in 1869. Schmidt pointed out that in Esthland, in the lower parts of the country, and in the former inlets of the Wick, there is a stratified dark clay, sometimes occurring alone, and sometimes covered with fine or coarse sands containing shell fragments, like that now being deposited in some places by the sea, and which has its equivalent in Sweden in the old inlets of the Mälar Sea. Schmidt declared this deposit as it occurs in Esthland to be of fresh-water origin, and he said it there everywhere covers the widely spread angular gravel known to the natives as Richk or Plink. He goes on to say that while in the raised beaches and terraces and deposits on the coast of Esthland remains of marine shells occur, these are not found in the interior of the country. They overspread the lowlands of the islands of Dago, Worms, Nuckö, and the neighbourhood of Hapsal. In Dago they occur at a height of 30 or 40 feet above the sea-level,

and, at Pönal and Pallifer, at a distance of 20 versts from the water. Further inland, he adds, no such marine shells occur, but only fresh-water shells such as *Ancylus fluviatilis* and pieces of *Unios*.

On the mainland he found the same deposit with *Ancylus fluviatilis* at Mannalas at a considerable elevation, at Padis in gravel, and mixed with *Paludina baltica* near the church of Karusen. In some places the latter shell occurs alone. He remarks that hitherto *Ancylus fluviatilis* had not been found in the sea and only in running streams. Its near relative *Ancylus Baicalensis* is found in Lake Baikal with certain marine Crustaceans, pointing to the former union of that great lake with the Polar sea. The two shells above named also occur in the gravel mounds on the top of the island of Mohn (op. cit., pp. 55, 56).

In 1881 Geikie published his work "Prehistoric Europe," in which he has a paragraph about these fresh-water beds which is interesting as showing that the problem had then been considerably illustrated by Krapotkin and Schmidt, although he unfortunately (as Munthe also complains) does not give a reference to the memoir where their researches were published, and which I cannot trace. They argued, according to Geikie, that in Finland the fresh-water beds were older than the marine ones, and that the Gulfs of Bothnia and Finland existed at the end of the Glacial period as great fresh-water lakes, and they quote the terraces which mark their ancient margins as being found there, as they are on certain islands of the Baltic, such as Mohn and Dago. Similar terraces at higher levels have been traced in the interior of Finland up to 150 feet. "The whole region . . . . seems to have been covered, over wide regions, with extensive sheets of fresh water. In many cases the natural dams which held in their waters consisted of *åsar* or great gravel ridges that were rendered watertight by the mantle of loam and silty clay which often cloaks their slopes. The different levels of the ancient lakes as their confining barriers gave way are marked by terraces eroded in the sides of the *åsar*. It is remarkable that . . . . . not a single sea-shell has yet been detected in the interior of Finland" (Geikie, op. cit., p. 470).

In 1884 Schmidt published a memoir in the Zeitsch. der Geol. Gesellsch. on the Glacial and post-Glacial deposits of Esthland, Oesel, and Ingermanland, in which he added some further facts to those here stated. He there tells us that the fresh-water shells occurring in the beaches consist in the main of *Ancylus fluviatilis* and *Limnæa ovata*, but there are also found *Unio*, *Cyclas*, *Paludina impura*, and *Neritina fluviatilis* var. In Oesel these beaches occur near Arensburg from a height of 20 feet up to 100 feet in the higher parts of the island. In Mohn they occur in the highest part of the island, near the church; while on the mainland our author reports them from Karusen, St. Michaelis, Fickel (Awaste), Piersal, Mannalas, Kegel, Hirro near Reval, and further east below the Jaggowalschen waterfall. Still further east the same beds, but without shells, occur at Kuckers, Sackhof, etc.

Schmidt in describing these deposits confesses himself unable to say

whether the fresh-water beds are older than the marine (now called *Litorina* beds) or not. He adds, however, "Vielfach sieht man aber marine Sande auf Bänderthon aufliegen, der, wie gesagt stellenweise Becken bildet, die von Ancylusschichten umsäumt sind"; and says further, what I cannot quite understand, "Die hohe lage dieser Schichten auf Mohn sprecht dafür, dass bei ihres Bildung die Insel noch nicht von Festlande getrennt war. Vielleicht war den ganze Riga'sche Meerbusen ein Süsswasser becken" (op. cit., p. 266).

In 1884 Munthe recognized similar fresh-water beds at the height of 130 feet south-west of Wisby in the island of Gotland, in which he observed *Limnæa ovata* and *Pisidium ovatum*.

In the same year Holm, in a letter to Holst, implied the occurrence of these fresh-water beds in Gotland, and also foretold their occurrence in Öland (see Holst, Sver. Geol. Unters., No. 180, p. 96, note), which he definitely proved two years later in a paper published in the Geol. Fören. Stock. Förh., 1888, vol. x, p. 365.

In a visit to Gotland made in 1886 and 1887 Munthe found similar deposits at a height of 100 to 150 feet marked by the presence of *Ancylus fluviatilis*. These beds consisted of typical open beaches with pebbles and sand. Munthe tells us that in 24 sites where they occurred in Gotland *Limnæa ovata* was represented in 23, *Ancylus* in 19, and *Pisidium* in 10. In addition there were found in them *Limnæa palustris*, *Planorbis contortus* and *marginatus*, *Valvata cristata*, *Bythinia tentaculata*, several other species of *Pisidium*, including *amnicum*, *pallidum*, *fossarium*, *pusillum*, var. *major*, and three species of Ostracoda, *Cypris reptans*, *Candona compressa* and *candida*.

Munthe gives a map of the localities in the south-east of Gotland, such as När, Lau, and Burs, as well as the limestone ridges called Burgen where these deposits have been found.

In Öland Holst says that the *Ancylus* and *Litorina* beds are found well developed in the villages of Mörbylånga, Resmo, and Vickleby, on the western side of the island, although they are not so abundant there as they are on its eastern side (Sver. Geol. Und., No. 180, p. 95, note).

The occurrence of these fresh-water deposits in so many localities upon open beaches facing the sea, on the mainland as well as on the islands in the Baltic, enabled Munthe to make the very important generalization embodied in his paper already cited, and published in 1887, namely, that the Baltic was once a fresh-water sea or inland lake, and that this stage immediately preceded the *Litorina* stage in its history, since the *Litorina* beds are found overlying the fresh-water ones. From these beds being especially characterized by the shell *Ancylus* he gave them the name of *Ancylus* beds, and the sea in which they were found the name of the *Ancylus* sea.

The *Ancylus* has an outward resemblance to the limpet, and has sometimes been called the fresh-water limpet. It was, in fact, called a *Patella* by Linnæus. The northern geologists give the *Ancylus* we are discussing the specific name of *fluviatilis*, but this involves a difficulty. The shell so called is apparently limited in its habitat

to shallow rivers and streams, where it occurs on stones and rocks. Jeffreys says he once found it (apparently meaning only once) of a dwarf size in a stagnant pool near Swansea, into which no stream had flowed within the memory of man, in company with *A. lacustris*. The latter shell is described by him as found on the leaves of water-lilies and other aquatic plants, as well as on fallen leaves of trees, in slow rivers, lakes, canals, marshes, and ponds, from Finland to Algeria. He identifies it with the *Patella lacustris* of Linnæus. Munthe says his *A. fluviatilis* is not only a fresh-water but a marine shell, and that he has taken it alive adhering to marine species of algæ in the Baltic (G. Jeffreys, op. cit., i, 122, 123). This latter statement makes it somewhat inconsequent to name the fresh-water sea of the pre-*Litorina* time from this shell instead of from one of the purely fresh-water forms with which it is associated.

Munthe points out the remarkable fact that the *Ancylus fluviatilis* which, he says, characterizes the fresh-water beds we are describing is not found living in the streams of Gotland. It occurs, however, in the brooks of Esthland. The fossil specimens are small and dwarfed, being 3 mm. long and 2 high, compared with the living forms. The largest specimens from the fossil beds elsewhere are 5 mm. long, 4 broad, and 3 in height, while the largest living ones from Ruysjon in Skäne are 4 mm. long and 2 high (see Overs. K. V. Ak. F., 1887 and 1888, p. 724).

These proportions seem to point to the fossil shells in question belonging to *Ancylus lacustris* rather than *fluviatilis*, for, as my friend Mr. Sherborn has pointed out to me, the chief distinction between the two shells is that one is much rounder than the other, which is more oval. As they occur in places together it may be that the forms grade into each other, at all events Forbes seems to have treated them as of one species. The matter deserves a more minute analysis at the hands of the Scandinavian geologists. Let us return, however, to the distribution of the fresh-water beds we are discussing.

The case was carried further when certain clays, not then known to be fossiliferous, which were discriminated by Von Post as far back as 1855, and were called by him 'undrediluviallera,' i.e. lower diluvial clay or lower clay, were identified with the *Ancylus* beds by Munthe. Von Post described them as found as high as 75 metres above the sea-level, and as consisting of a light grey or blue grey to dark grey bed, with little or no tendency to lamination, and when dry falling apart into fine fragments, and as containing concretions of iron oxide formed round roots from above.

Erdmann and writers in the Sveriges Geologiska Undersöknings called this clay 'undre äkerlera' (underlera), while Munthe, who identified it with the clay of his fresh-water sea, called it *Ancylus* clay. It has been recognized as existing in Upland, Vestmannland, and Nerike, and probably in various parts of Eastern Sweden (op. cit., p. 263). At Skattmansö, in Western Upland, these *Ancylus* beds are found of a thickness of 3·55 metres and at a height of 36 metres above the sea, and containing a large number of fresh-water diatomaceæ, including the now probably extinct *Eunotia Clevei*,

which has occurred in other *Ancylus* beds (Nathorst, Sveriges Geologi, pp. 258–266).

De Geer has calculated that the *Ancylus* sea extended over 570,000 square kilometres (220,000 miles), and included the whole Baltic area with Finland and Lake Ladoga (see Nathorst, op. cit., pp. 258 and 259, where a map of the *Ancylus* sea is given).

The facts here mentioned, and others similar to them, have satisfied the Northern geologists that the recent history of the Baltic involves its having been first a widely spread fresh-water sea and then a brackish-water one, more salt than the present Baltic, which has gradually become less salt until it acquired its present condition.

The change here mentioned, from a fresh-water sea to a brackish one, involved one inevitable corollary, namely, that at a not remote time in its history the Baltic must have been entirely shut off from the North Sea and been a completely enclosed lake. This conclusion, again, has been found to exactly harmonize with other evidence forthcoming from other sources, and which I will shortly condense.

Anyone who looks at the broken and irregularly outlined Danish islands, separated by their narrow sounds and belts and partially closing up the space between Jutland and Skäne in Sweden, will be impressed by their resemblance to a ruinous remnant of a formerly continuous land surface. This appearance is fully borne out by the actual evidence, which proves that the whole area has sunk considerably in comparatively recent times. A movement of elevation subsequently intervened and affected a portion of the sunken surface. This is very plainly shown by the fact that all along the coast of Skäne and elsewhere in this area the marine beds of recent origin, which are found at a small elevation above the sea and whose shells show they belong to the *Litorina* period, frequently lie upon turf or upon beds containing land shells and land plants, as has been pointed out by many observers. This proves that the district in question, which was once dry land, has at one time been sunk below the water sufficiently deeply and long to get a covering of marine deposit upon it, and has been then raised again to its present level. The first person who argued that the land off the coast of Skäne had sunk was J. C. Wilcke, who, writing in 1770 in regard to the harbour of Landskrona, notices how in the banks bounding its entrance and which are covered by five or six feet of water there are found trunks of rotten and upright trees, showing that the submerged ground was once a wood, and tells us how he had been told in 1767 that a large oak with its trunk and branches intact had been found under six feet of water.

On the oyster ground Wilcke found decayed trunks in a layer of submerged mould, in which they had probably grown, and he considered the layer of soil marked the former level of the land, which had therefore been about five feet below the main level of the water. These facts led him to the conclusion that there had been a considerable subsidence along the coast.

In 1847 Nilsson published his well-known work on the

Scandinavian fauna. In this he enlarged, *inter alia*, on the evidences of a general sinking of the land in very recent geological times along the coast of Skäne. He mentions the discovery of submarine turf in many places along the coast from Dybeck as far as the district between Trelleborg and Falsterbo. Over 200 feet from the shore is a bed of turf about two feet deep under the sea and six feet thick. A similar bed of peat lies near the fishing village of Skäre. Again, three-quarters of a mile from the land and on the ground known as Falsterbo there lies a great mass of peat of several acres in extent and 10 to 12 feet in thickness. It is 24 to 26 feet below sea-level, and contains various kinds of land and fresh-water products; *inter alia*, it contains a number of large and small trees, such as oak, birch, alder, aspen, and fir, mixed with leaves in all its various layers, of hazel, willow, sallow, together with hazel-nuts, pine cones, Equisetæ, etc., etc. (Geol. Fören. Stockholm Förhandlingar, i, 101).

Nilsson by careful measurements at Falsterbo has shown that the sea has gained considerably on the land. A small island called Kläppen has almost disappeared, while extensive beds of submarine turf formed in fresh water are now found at a depth of from 10 to 14 feet below the surface of the sea. These submarine turbaries, he says, occur in many places, some near the present coast and some at a great distance away and at great depths. In enlarging the port of Malmö in 1874 a submarine turbary was found containing flint flakes.

During the years 1874–5 some excavations were made in the port of Ystad, which were closely watched and reported upon by M. Bruzelins, then living there. The space reported upon by him consisted of three Swedish acres or six French hectares. The surface layer of the deposit was sand, below which, and at a depth of three metres below the mean level of the water, there was a peat bog varying from 40 to 25 centimetres in depth. In this peat were a number of trees still attached by their roots. Below the peat was a layer varying in composition, sometimes sand, sometimes blue clay, and sometimes a mixture of sand and clay, and containing many striated pebbles.

In the bed of sand above the peat were shells of *Mytilus edulis*, *Mya arenaria*, *Tellina balthica*, and *Cardium edule*, mingled with the wreckage of 38 ships, one of which, loaded with tiles, dated from the middle ages, and there were found a number of objects of metal —caldrons, etc., two arquebuses, dating probably from 1450 to 1500, and six cannon-balls. There were also found a number of other domestic objects, enumerated by Bruzelins, all probably dating from two to four centuries ago, together with a large number of skulls and bones of oxen and horses, skulls of dogs, swine, sheep, goat, and roebuck, bones of the fox and cat, and one or two human jawbones. All the objects in this layer belonged to the modern world, and none reached back to pagan times or the earlier part of the middle ages.

In the peat below the sand were many roots of aquatic plants.

In the peat Professor Torell found a number of forest-living shells, such as *Helix, Clausilia laminata, Vertigo costulata, Zua lubrica, Succinea putris,* etc., besides which were a number of fresh-water shells, including three species of *Limnæa,* eight of *Planorbis,* two of *Bythinia, Physa fontinalis, Ancylus lacustris, Valvata cristata, Anodonta,* etc.; there were also elytra of aquatic insects, branches, leaves, and fruit of trees such as oaks, hazels, alders, etc., and aquatic plants such as *Calla, Myriophyllum, Ceratophyllum, Nuphar,* etc. Only three tree trunks occurred, one of oak and two of alder.

In the sandy clay below the peat there occurred at a depth of 30 centimetres a knife of grey flint; six inches from this was found a polished and broken axe of yellowish flint, at a depth of 15 to 20 centimetres a mace of bronze with four projecting points and twelve round studs on it, a dagger, a knife of flint 20 centimetres long and with its point broken, some bone objects which looked as if they had formed part of a sledge, two objects which gave rise to some discussion afterwards; and, lastly, two pieces of bone which had served to haft a knife, which were artistically wrought and terminated with the head of a dragon. These objects M. Bruzelins dated approximately between the eighth and eleventh centuries, and he argued that the subsidence of the peat bog had taken place some time between the eighth and eleventh centuries.

In the discussion which followed M. Bruzelins' paper at Copenhagen, C. Vogt and Bertrand urged that the subsidence of the ground as evidenced by the majority of the facts mentioned, took place some time during the Stone or Bronze age, while the presence of the solitary object, the knife handle, was accidental and explainable in another way (see Comptes Rendus Cong. Prehist. Arch. Copenhagen, 1873, pp. 15–30).

Nathorst says that round the coasts of Zealand are found similar witnesses to a post-Glacial sinking of the land as in Skäne, in the shape of peat bogs and submerged river-beds under the sea. Subsequent elevation of the ground has again raised these beds as in Skäne above the sea-level, the latter process being evidenced by the turf beds being covered with marine deposits. These contain the same kind of shells as do the raised beaches on the opposite coasts of Skäne, namely, *Cardium edule, Mytilus edulis,* and *Tellina balthica,* and where the water is deeper and salter *Litorina litorea* and *Nassa reticulata* (Sveriges Geologi, p. 277).

A submarine forest has been reported from the south of the island of Bornholm. Similar evidences are also forthcoming from the district further south; thus, according to Dr. Maack the remains of the Schleiermünder Burg on the coast of Schleswig-Holstein are now always submerged by the sea, and the ancient Bramhorst near Probstei has disappeared; the stumps of the trees forming the forest of this ancient shooting lodge are now to be found under the sea at a distance of 400 or 500 feet from the shore, and two great rocks near Travemünde called Krüger and Möwenstein, which were on the shore 90 years ago, are now surrounded with water. Nilsson, in fact, concludes from these and other observations that Scania and

Mecklenburg were once united by a land-bridge, and it was over this that the animals whose remains are now found in the bogs of Scania crossed over (Comptes Rendus Prehistoric Congress at Copenhagen, 1875, pp. 53–61).[1]

In addition to other evidence of the land-bridge such as is here quoted Erdmann refers to the fact that in the whole of the South of Sweden from the southern coast of Scania, as far as Halland and Småland, the country is entirely covered with angular débris and contains neither rolled pebbles nor clays except on the eastern and western coast, whence he argues that it was never under water, and he continues:—"Une forte part du continent scanien était, selon toute probabilité, réunie alors avec les îles danoises et les plaines actuelles de l'Allemagne du nord, et il existait de la sorte un pont naturel sur lequel pouvaient immigrer, du grand continent européen, les espèces animales dont nous trouvons de temps à autre les squelettes dans cette province de l'extrême sud de notre pays. La découverte faite par Nilsson des restes de ces animaux dans le sol scanien, faisait déjà présumer, il y a long temps, à ce savant célèbre, la presence, dans les temps reculés, d'un pont naturel entre la Suède méridionale et le continent. Mais, autant que je sache, le fait même que, dans cette partie de la Scanie, les dépôts glaciaires consistent presque exclusivement de glacier anguleux et qu'ils sont par conséquent d'une formation continentale décidée, n'a jamais été remarqué jusqu'ici, et encore moins la conclusion que l'on en peut tirer" (Erdmann, "Exposé des formations Quaternaires de la Suède," pp. 73, 74).

There is abundant direct evidence, therefore, of the former existence of a land-bridge between Skäne and the mainland of Denmark and Mecklenburg, the breaking through of which converted the fresh-water *Ancylus* sea into the salt-water *Litorina* sea. The next question is when did this breach occur. The Swedish geologists and antiquaries are of one mind that it took place after man had begun to inhabit Sweden and during the so-called Stone age. Of this there is a good deal of interesting evidence.

First let us consider the case of the so-called Jära wall. This great rampart, which runs along the sea-coast in the south of Scania from Ystad to a league beyond Trelleborg is essentially an *äs*, and is composed, like the äsar of Central Sweden with which it has been compared, of sand and rolled gravel. There can be small doubt from the facts mentioned below that (as the Swedish geologists agree) it belongs to the time of the *Litorina* sea and was a product of the *Litorina* age.

Nilsson speaks of a peat bog under the Jära wall having a thickness of 10 feet; 2 ft. 3 ins. of which lies above and 7 ft. 7 ins. below

[1] This may be the same submerged forest mentioned by Forchhammer, who says it is situated between the island of Römöe and the dukedom of Slesvig, and that it is nine feet below high-water mark, and that its roots are still seen branching out into the sand. The fishermen say this forest consisted of fir. At other places far beyond the present shore forests of oak are found in the same situation below the mean level of the sea (Geol. Trans., ser. II, vi, 157–160).

the surface of the sea. The turf under this ridge is so compressed that when dry it is almost as hard as brown coal pressed together, and when a fir chip is broken it is found to be black and shining in the cross sections, all the results of great pressure and of age. The turf has been, as in the submarine peat bogs which lie outside Falsterbo already mentioned, formed in fresh water. The bottom of it, when the turf was formed, lay above the surface of the sea, inasmuch as in it were found the same species of plants as those that are found in the other Scanian peat bogs situated farther in the interior of the country. At the bottom of this peat bog, on the pure blue clay itself, there have frequently during the cutting of the turf been found arrows, knives, etc., of flint, which he urges proves that human beings already existed in these districts at the time when the bog was an open water and peat began to grow in it. Consequently there were people here even before the great phenomenon which raised the ridge in question, and caused a wide opening between the South of Scandinavia and the North of Germany.

Bones of the cave bear have been found in the turf under the Jära wall, and also at the bottom of other peat bogs, with bones of the reindeer—for instance, in the peat bog in Kullaberg, in which flint flakes have also been found in great numbers. We may therefore suppose that these peat bogs are coeval with the one under the Jära wall, and, consequently, they also are more ancient than this remarkable ridge. In these ancient peat bogs there has never been found a trace of metal, and therefore we can likewise conclude that the above-mentioned cataclysm took place during the Stone period, and during an early part of the Stone period, since not a single stone axe or any other ground stone was found there, but only flint flakes, arrows, and knives. No human skeletons have occurred in these beds, but inasmuch as round skulls have been found in the old peat bogs of Scania the flint flakes, etc., were probably made by a round-headed race.

In a paper on the Jära wall, etc., Torell, in the Comptes Rendus of the Int. Cong. of Arch. at Stockholm, pp. 867–868, calls attention to the fact that Nilsson had subsequently found a chambered tomb of the Stone age containing amber, on the Jära wall itself, and this goes to show that the famous rampart in question was formed between the time when the rough flint chips were used, i.e. the so-called kitchen midden time and that of the later Stone age.

The facts that Nathorst has since found marine shells of the *Litorina* time underlying the Jära wall, while Munthe, in vol. ii of the Transactions of the Upsala Institute, p. 363, reports the finding of a bone implement in *Ancylus* clay at Norsholm in Ostro-Gothland, show respectively that man was living in Sweden in the *Ancylus* time, and therefore before the Baltic breach; and, secondly, that the Jära wall was distinctly a product of the succeeding period, namely, of the *Litorina* age.

In 1856 Forchhammer contributed a paper to the Nordisk Universitets Tidskrift, in which he enlarged considerably on Nilsson's and Erdmann's conclusions. He pointed out how at

Husum in a submarine peat bog, or immediately under the same, there was found a grave mound dating from the Stone age, and also in other places flint knives and pieces of burnt clay dating from the Stone age. Among the plants from this submarine turf he mentions birch, oak, spruce, and hazel, but he mentions no beech.

I may further add that similar flint tools to those above mentioned have been found in the ancient submerged forest outside Landskrona, while A. F. Cadson has similarly found flint tools in the submerged oak forest lying 300 to 400 metres outside the present beach at Limhamv.

At Islaby in Bleking, De Geer found a bone weapon a metre deep in a turf moss which was partly under the post-Glacial marine boundary and partly under a marine mud.

Lastly, Lindström found charcoal, together with bits of a fish skeleton, which had obviously come from a human feast, under a post-Glacial beach at Wisby, situated 15 metres above the sea (Nathorst, op. cit., pp. 308 and 309).

I will now turn to another kind of evidence. In J. Petersen's memoir, "Om de Skalbaer molluskers utbr. i de danske have indenfor Skagen," Copenhagen, 1888, p. 86, quoted by De Geer, we are told that he found on the bank called Böchers bank, east of Laeso, at a depth of 25 metres, *Litorina litorea* and other shore shells in a sub-fossil condition. He also found similar shells in a similar condition from 18 to 25 metres deep, between Anholt and Kullen, probably near Stora Middelgrund, and De Geer argues thence that the sea-bottom there was once at least 20 metres higher than at present, and that Anholt and Laeso were probably then connected with the mainland of Denmark (Geol. För. i Stockholm Förh., xii, 107).

The case seems, in fact, complete for those who urge not only that the proved succession of the fresh-water *Ancylus* sea by the salt-water *Litorina* sea necessitates our postulating the breakdown of a former land barrier between the North Sea and the Baltic, but that such a breach is amply attested by evidence of every kind, and further that it occurred comparatively lately, and probably during the so-called Neolithic age.

The next question that arises is one in which I cannot see quite eye to eye with the Northern geologists. Like their contemporaries in England, they are devoted to what I deem the quite fantastic development of Lyell's theory of Uniformity which now widely prevails, and they have consequently argued that the breach in question was a gradual and continuous one, due to the wearing away of the banks of the Sound and the Belts by the sea. To this view I cannot in any way subscribe. It seems plain to me that instead of this movement having been gradual and continuous, it was impetuous and rapid and even sudden.

In the first place there is everywhere a distinct gap between the *Ancylus* beds and the *Litorina* beds. Wherever they occur together there is an absolute failure of continuity between them. Nowhere, so far as I know, have we any mixture of the typical fresh-water shells of the *Ancylus* time with the typical brackish-water shells of

the *Litorina* time. The latter series of shells follows abruptly upon the former, and this abruptness seems to me to inevitably point to an abrupt breach in the conditions.

Secondly, the condition of the submerged peat bogs and of shallow-water beach gravels in deep water are quite inconsistent with a gradual denudation by which the coastline was eaten back. Such a process of gradual eating back would have entirely destroyed the peat bogs and disintegrated and dispersed the submarine sunken beach pebbles; the pounding and grinding of the shingle on exposed shores would not leave great stretches of peat with enclosed trunks of trees with masses of dead leaves, twigs, etc., lying in great slabs. The existence of these submerged peat-beds occurring in this fashion and of their contents unweathered and unworn, points to their having subsided rapidly or suddenly, so that they could not be acted upon by the tide, but remained safe and unweathered at depths where the sea does not erode.

Thirdly, if the opening of the land-bridge which once limited the fresh-water *Ancylus* lake had been gradual, we should have had a gradual addition of salinity to the Baltic waters until it reached a certain normal amount, when it would have become more or less stationary and not a culmination of the salinity at the inception of the *Litorina* stage and the gradual sweetening of its waters since. The high grade of salinity at the beginning of the *Litorina* time and its gradual declension since, is hardly explainable except as the result of a sudden inpouring of salt water due to a sudden or very rapid breakdown of the land-bridge.

Again, there is direct evidence that since the so-called Neolithic age there have been some cataclysmic phenomena which have caused considerable movements of water in this part of the Baltic. To one of these inundations some inquirers have given the name of the Cimbrian flood, and they have associated it with the well-known passage in Ammianus Marcellinus in which he says, "The Druids affirm that the inhabitants poured in from the islands on the coast and from the districts beyond the Rhine, having been driven from their former abodes by frequent wars, and sometimes by inroads of the tempestuous sea" (op. cit., xv, ch. 9).

More directly geological evidence of a similar fact is forthcoming. Thus, Forchhammer says that on the islands west of Sleswig traces of an inundation may be found to the great height of about 60 feet above the present high-water mark, which happened while the islands were inhabited by man, because we find tumuli partially destroyed by the inundation. The effect and height of this flood may easily be traced by a bed of pebbles, partly rounded, partly angular, containing now and then fragments of bricks, and easily distinguished from a beach by its occurrence in one single bed hardly a foot thick, undulating with the surface, and in one place found only a few feet above high-water mark, while at others it is about 50 feet above it. He considers it as the washing away of the finer materials, or the sand and sandy clay (Forchhammer, Geol. Trans., ser. II, vi, 160).

The existence of the great äs on the seaboard of Scania called the

Jära wall, already described, which overlies deposits containing objects of the Stone age and remains of Pleistocene beasts, and belongs therefore to the *Litorina* time, is another proof that the coming in of that period was accompanied by some cataclysm involving a great rush of water. Those who have attributed this great mound and rampart to the ordinary operations of the tide have surely entirely given up induction in their pursuit of the fantastic type of the doctrine of Uniformity, which is so fashionable and so entirely metaphysical. Nilsson, who was the first scientific man to critically explore the Jära wall, and who first really explained its history, was most emphatic that it was no result of slow secular movements of the sea, but of a cataclysm on a great scale, probably coincident with the first inrush of the salt water to the Baltic on the breakdown of the land-bridge.

Turning from this great äs of Southern Sweden to the äsar of Central Sweden and of the islands on the coast of Esthland, whose upper beds are in some cases full of the débris of the *Litorina* sea, we are constrained to the same conclusion.

The äs at Enköping is a typical instance of an äs in which the upper layers are intercalated with beds containing shells dating from the *Litorina* time. They occur chiefly along the portion of the äs extending from the church to the tilery, which runs from about 102 to 130 feet in height. The richest deposits of shells of the beds occur on the south-eastern slope of the äs, and at one place a bed several feet thick occurs which is almost entirely composed of broken shells of *Mytilus edulis* and *Tellina balthica*. This south-eastern slope has an angle of from 20 to 25 degrees, and its upper layers consist in descending order of—

| | Feet. |
|---|---|
| Gravel with rolled pebbles ... ... ... ... ... | 2·5 |
| A bed of shells very argillaceous ... ... ... ... | 3·0 |
| Sand and gravel with a few rolled pebbles ... ... | 1·0 |
| Clay without shells ... ... ... ... ... | 0·5 |
| Sand and gravel with a few rolled pebbles ... ... | 1·0 |
| Shelly gravel ... ... ... ... ... ... | 0·3 |
| Sand and gravel with a few rolled stones ... ... ... | 1·0 |
| Clay (styled glacial) without shells ... ... ... | 0·5 |
| Sand and gravel with rolled stones ... ... ... | 3·5 |
| Sand as far as the bottom of the trial pit ... ... ... | 10·0 |

On the north-west or opposite slope of the äs the beds were—

| | Feet. |
|---|---|
| Fine gravel ... ... ... ... ... ... ... | 1·0 |
| Shelly gravel (chiefly with *Mytilus*) ... ... ... | 0·3 |
| Fine gravel ... ... ... ... ... ... ... | 0·5 |
| Shelly gravel without clay ... ... ... ... ... | 0·2 |
| Fine gravel ... ... ... ... ... ... ... | 0·3 |
| Shelly gravel without clay ... ... ... ... ... | 0·7 |
| Fine stratified sand ... ... ... ... ... ... | 3·0 |
| So-called glacial clay with threads of sand ... | 5·6 |
| Sand ... ... ... ... ... ... ... | 6·0 |

The äs is traversed by a valley leading from the tilery to the plain from north-east to south-west, which is covered with typical black clay containing *Mytilus edulis*, and in its upper layers is filled

with vegetable débris of different kinds, as for example branches of *Equisetum limosum* mixed with fragments of conifers and leaves of the oak, willow, and poplar, needles and cones of *Pinus sylvestris*, cones, branches, and bark of the fir (*Abies*) and the poplar, remains of a *Sparganium* with leaves of grass, of *Ledium palustre*, etc. Erdmann argues that the *Equisetum* lived at the margin of the water, but that the other débris were transported by running water ("Exposé des formations," etc., pp. 95 and 96).

These facts seem to me to point to some interesting results. It is probable that the shells are not all *in situ* on the äs. They are fragmentary and transported. Nor is it quite easy to see how they could well have lived on the two slopes of the äs, which rises like a rampart from the adjoining low country, and in no way forms, or could ever have formed, a boundary to the sea. The shells in question are distinctly shore shells, and could hardly again have lived both on the top of the äs and also at the bottom of the valley cutting through it, where they are also found, at the same time, and the question may well be raised whether these upper beds can be explained by any other process than a cataclysm, and whether, as in the case of the Jüra wall, they were not laid down in a violent way at the time when the bridge was broken down separating the outer sea from the great *Ancylus* lake, when a great inrush of water must have taken place. This seems to be the only way of accounting for the facts, which will also account for the finding of many very large erratics on the crests of some of the shell-bearing äsar, which must have needed some gigantic force to move them.

It seems quite preposterous in this case to appeal to ice-portage, for the climate of the country during all the *Litorina* time was, as we shall see in a later paper, as mild or even milder than it is now. Apart from this there are not, and never could have been, icebergs in the Baltic, certainly not at a time when the present flora occupied the land. The only ice available would be shore ice, but shore ice is only found and only acts on sea-beaches. It cannot reach up to 150 feet above the water-level, which is the height of this äs. If the äs was already there when the shells and also the boulders were deposited, there can be no question of its having been there as a beach barrier. The fact of the shells occurring on both slopes forbids such a notion, as does the whole arrangement of the beds in the huge mound. Nowhere that we know of are beach ramparts being formed in the fashion of these äsar. Anyone who will visit them and tramp over them for miles, as I have done, and sit upon and contemplate the size of the erratics on their back, and the conditions and surroundings, physical and biological, in which they occur, and who still pleads for ice as the transporter of the stones which lie in and on their current-bedded sands and gravels with such shells as *Mytilus* and *Cardium*, seems to me to have abandoned science for romance and metaphysics, and this may even be the case with some prominent and very confident advocates of what is called moderate glacialism.

I propose to return to the question in another paper. Meanwhile

let me support the position I am maintaining by an appeal to two of my old masters, whom I have tried to imitate at least in one respect, namely, by a patient and laborious exploration of these äsar on the spot, and not in the method by which the German philosopher made his camel.

First, Murchison, who had no doubt about the äsar having been the products of aqueous and not of ice action. Murchison refers to the shells of the Baltic Sea as previously mentioned by Lyell as occurring in a blue clay beneath the great mass of äsar drift, indicating in the clearest manner a submarine condition when the drift was transported (Q.J.G.S., iii, p. 365). Again, he says, "In the sandy and gravelly beds of the äs on which the castle of Upsala stands Mr. Macklin found several species of shells, including the *Tellina balthica*; other argillaceous beds of blue clay which occupy the banks of the river, on either side of which the äsar rise up, are also in some spots absolutely loaded with this shell, showing that the whole base of the soft and overlying formations is truly of aqueous origin of no very distant date, the shells being specifically the same as those now living in the adjacent Baltic and exhibiting their nacre perfectly preserved" (id., p. 369).

Lyell in describing the äsar of Sweden says they were certainly produced under the sea. They usually consist of stratified sand and gravel, the layers being often at high inclinations, but where they are composed of boulders no stratification is observable. After a long search he says he found shells in a layer of marl in a ridge near Upsala, about 12 feet below the summit of the ridge and 80 above the sea. The shells are the commonest now in the Baltic. On the summit of the ridge he noticed angular masses of gneiss and granite from 9 to 16 feet long, *which had evidently been lodged when the ridge was submarine.*

Elsewhere he speaks more definitely.

"In Sweden," he says, "in the immediate neighbourhood of Upsala, I observed in 1834 a ridge of stratified sand and gravel, in the midst of which occurs a layer of marl, evidently formed originally at the bottom of the Baltic by the slow growth of the mussel, cockle, and other marine shells of living species intermixed with some proper to fresh water. The marine shells are all of dwarfish size, like those now inhabiting the brackish waters of the Baltic; and the marl, in which myriads of them are embedded, is now raised more than a hundred feet above the level of the Gulf of Bothnia. Upon the top of this ridge (one of those called osars in Sweden) repose several huge erratics, consisting of gneiss, for the most part unrounded, from 9 to 16 feet in diameter, and which must have been brought into their present position since the time when the neighbouring gulf was already characterized by its peculiar fauna. Here, therefore, we have proof that the transport of erratics continued to take place, not merely when the sea was inhabited by the existing testacea, but when the North of Europe had already assumed that remarkable feature of its physical geography which separates the Baltic from the North Sea, and causes the Gulf of

Bothnia to have only one-fourth of the saltness belonging to the ocean.

"I cannot doubt that these large erratics of Upsala were brought into their present position during the recent period . . . . The Upsala erratics may belong to nearly the same era as the refuse heaps (i.e. the Danish kitchen middens)." ("Antiquity of Man," pp. 281–2.)

This is a remarkable conclusion for a man of Lyell's views to have arrived at, and it clearly shows that in his view the äsar, or some of them, actually dated from so recent a time as the Neolithic age, when the climate of Northern Europe was milder than it is now, and when ice-portage, as necessitated by the glacialists' theories about these and similar erratics, are quite out of court.

I quote it as showing that Lyell had no hesitation in attributing the formation of the äsar and the distribution of the enormous erratics which crowd their backs to the action of water, and not to that of ice, a fact for which I have made a vigorous fight in my work recently published. It seems to me, however, that the water we must appeal to in such a case is not the sea in its normal moods, but the sea when under the influence of some cataclysmic impulse such as I have shown to have probably initiated the *Litorina* stage of the history of the Baltic. If this is to be appealed to as the fashioner of the äsar it may be that we have been too sanguine in treating all the more recent raised shell-beds in the Baltic area as measures and indices of the former permanent level of the sea, and that they may rather mark the level at which the huge tide caused by the breach in the old land-bridge deposited its load of débris. I may revert to this issue in another paper.

## EXPLANATION OF PLATE XIX.

I.

Map of the Baltic as it is now and as it was at the maximum limit of the *Litorina* Sea. After De Geer. Nathorst, Sveriges Geologie, p. 267.

II.

Fig. 1. *Cardium edule* (dwarfed form) from Gotland.
,, 2. *Cardium edule* (normal growth, natural size) from the Cattegat.
,, 3. *Tellina balthica* (dwarfed form) from the äs at Enköping.
,, 4. *Litorina litorea* (dwarfed form) ,, ,,
,, 5. *Litorina litorea* (normal growth, natural size) from the Cattegat.
,, 6. *Paludinella balthica* (dwarfed form) from Gotland.

(See Nathorst, Sveriges Geologie, p. 270.)

Figs. 2 and 5 give the normal growth of *Cardium* and *Litorina* and their natural size at the Cattegat, where they enjoy the full amount of salt water. Figs. 1 and 4 show the same species of shells from Gotland and Enköping, dwarfed by the decreased salinity of the waters as one recedes from the ocean towards the inner recesses of the Baltic. The *Tellina*, Fig. 3, is a similarly dwarfed variety; but Fig. 6, *Paludinella*, a fresh or brackish water shell, owes its degeneracy to too saline conditions.

### Errata in the previous Paper.

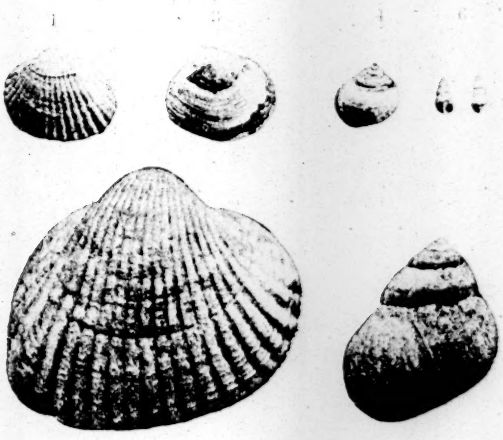
Page 311, line 8; 317, l. 42; 318, l. 38; and 320, l. 9, *for* De Geers *read* De Geer.
Page 314, l. 29, after *balthica*, insert *Scrobicularia piperata*.
Page 318, l. 10, *for* which *read* what; and l. 17, *for* wash *read* mark.
Page 319, lines 1 and 16, *for* Lomberg *read* Lönnberg; and l. 40, *for* has *read* have.

I.

THE BALTIC

As it is now and as it was at the maximum limit of the Litorina Sea. After De Geer. Nathorst, Sveriges Geologie, p. 267.

II.



THE BALTIC SHELLS.

Figs. 2 and 5, shells from the Cattegat. Figs. 1, 3, and 4, dwarfed by excess of fresh water in the interior of the Baltic (see Explanation of Plate, p. 352).

## II.—The Lower Carboniferous Problem in Devonshire.

By A. J. Jukes-Browne, B.A., F.G.S.

WHAT represents the Carboniferous Limestone in Devonshire, is a question that has often been asked, but has never yet been answered in a satisfactory manner. The question has recently been narrowed by the identification of the Coddon Hill Beds and the *Posidonomya* limestones with the shales, cherts, and limestones which overlie the mass of the Carboniferous Limestone in South Wales,[1] and with the Pendleside Beds which occupy a similar position in Staffordshire, Derbyshire, and South Yorkshire.[2] Dr. W. Hind considers these beds to be more intimately connected with the Upper than with the Lower Carboniferous Series, and in any case the homotaxial equivalent of the main mass of the Carboniferous Limestone must be sought for below them.

If the upward succession from the Pilton Beds be continuous and unbroken—and there is good reason to believe that it is so near Barnstaple and again near Bampton—the question has now been narrowed down into small limits; for the whole Lower Carboniferous Series must in that case be represented either solely by the narrow band of dark shales (Fremington Beds) which intervenes between the Pilton Beds and the chert beds of Coddon Hill, or else by these shales together with a certain portion of the Pilton Beds. Further research may reveal a purely Carboniferous fauna in the higher part of the latter, but hitherto no such exclusively Carboniferous assemblage has been found in them, and the problem, so far as North Devon is concerned, remains as much of a puzzle as ever.

Hitherto, however, the problem has always been attacked by comparing the succession in North Devon with that of areas further north, and endeavouring to find equivalents for the limestones and shales of the Lower Carboniferous Series which have so great a development over both England and Ireland. In other words, it has been tacitly assumed that this series must not only be represented in Devon, but that the thickness of its representative must be comparable to that of the more northern facies, whether that of the Bristol area, or of South Wales, or of the south of Ireland. This assumption involves the further supposition that the Carboniferous sea continued to be as deep or even deeper to the southward than it was along the latitude of South Wales and South Ireland, so as to allow of the deposition of a similar thickness of sediment.

These assumptions may have hindered the solution of the problem, and it has occurred to me that it might be profitable to approach the question from the south; for if the representative of the Lower Carboniferous Series on the southern side of the great Culm-

[1] See Summary Prog. Geol. Survey for 1900, p. 87.

[2] By Dr. Wheelton Hind in Geol. Mag., Dec. V, Vol. I, p. 392 (1904).

measure trough is as feeble as it seems to be on the northern side, and if we can find any clue to the explanation of this phenomenon in the south, it may be applicable to the northern area.

There is also this advantage, that the surveys and researches made by Mr. Ussher have established the Devono-Carboniferous succession in South Devon and North Cornwall, which was formerly such a doubtful matter. It now appears that in this area there is a much more concentrated type of Upper Devonian, consisting mainly of slates with interbedded volcanic rocks, and that its total thickness is much less than in North Devon, so that there is less doubt about the delimitation of the Devonian and Carboniferous systems. It is true that the actual passage from one formation to the other has not yet been recognised in section, but the limits within which the transition may lie are much narrower.

On the other hand, Mr. Ussher's work has shown that the succession of the Lower Culm Series in South Devon is similar to that in North Devon, being as follows :—

4. Dark shales and mudstones with occasional limestones (Posidonomya Beds).
3. Hard cherty shales and chert beds (Coddon Hill Beds).
2. Hard dark mudstones.
1. Dark grey shales.

The beds below the cherty group are well developed near Ashton and Trusham on the north-east side of Dartmoor, and are probably part of the normal succession along the northern and western portions of the area, but are seldom seen in actual infra-position to the chert beds. The beds are everywhere so flexured and faulted that Mr. Ussher has never yet ventured to publish any estimate of their thickness. It can, however, be easily gathered from his published descriptions of them that the thickness is relatively small, and in response to my earnest request for some approximate idea of their probable thickness he has kindly informed me that he thinks the Posidonomya Beds may attain 150 feet, that the chert beds and the hard mudstones below may attain 150 feet, and that he has never seen more than 25 feet of the basal dark shales, though it is quite possible that they have a thickness of 50 feet or more. He also tells me that although he has separated the 'hard mudstones' which underlie the chert beds, yet it is quite possible that they contain Radiolaria and belong to the Chert Bed group.

Mr. Ussher also wishes me to say that the statement of possible thickness is merely an expression of the probabilities of the case as impressed upon him by experience in the field. That, however, is all that is necessary for the object of this communication, and my readers will understand that the figures are not to be taken as measurements.

Another point of special interest about this southern area is the presence of contemporaneous volcanic rocks both in the Upper Devonian and in the Lower Culm. In the former they are of sporadic or local occurrence, but are specially prevalent to the north

of Plymouth. Of this district Mr. Ussher wrote in 1901[1]:—"Contemporaneous igneous rocks occur in the Upper Devonian in the immediate vicinity of the Wearde St. Erney and Efford sandstones, and these igneous rocks correspond to the lower part of the Devono-Carboniferous volcanic group." Again, he says that both near Saltash and Tavistock "volcanic rocks have been proved to occur in the Upper Devonian and throughout the Lower Culm-measures, but not in the middle Culm-measures."[2]

Finally, near Beer Alston, Middle Culm sandstones are found to rest directly on Upper Devonian slates, and to explain this he invokes local unconformity due to the volcanic disturbances in the district, remarking that "it is probable that the upheaval of the sea-bed was so irregular in the volcanic districts that Middle Culm-measures, elsewhere apparently conformable to the Lower Culm-measures (as regards position), were partly formed by denudation of the Lower Culm-measures, and so rest on Upper Devonian rocks."

The existence of volcanic rocks interbedded with the Lower Culm-measures has been known for many years; they have been described by Mr. Rutley,[3] who seems to have thought that Brent Tor was the principal volcanic vent, and that it might have formed a volcanic island in the Carboniferous sea. Similar rocks (tuffs, schalsteins, diabase, and dolerite) occur throughout the range of the Lower Culm, from Launceston on the west to Oakhampton and Belston on the east, and again still further east in the Ashton and Trusham district, where there is a marked development of tuffs and dolerites in the group that contains the Chert-beds. These intercalations are shown on Sheet 339 of the Geological Survey Map (new series).

From the passages above quoted, and from others which might be given, it is clear that Mr. Ussher connects the volcanic disturbances and eruptions with "a general elevation of the sea-bed either after or during the deposition of the Lower Culm rocks,"[4] and the production of a local discordance near St. Mellion. In this view he is very likely to be correct, for it is well known that upheaval is a frequent accompaniment of volcanic activity; but it seems to me that the supposition of such a movement will explain much more than a mere local unconformity. It will surely explain the small thickness and the character of the deposits which constitute the Upper Devonian and the Lower Culm-measures in South Devon.

With regard to the Upper Devonian the notable absence of grits or sandstones seems to indicate that the area of deposition was at some distance from any large area of land, while the small, sporadic, and lenticular developments of limestone show that the conditions were not favourable for the growth of calcareous organisms. When

[1] Trans. Inst. Mining Eng., vol. xx, p. 9 of reprint.
[2] The Wearde sandstones and associated volcanic rocks are now included in the Upper Devonian.
[3] Quart. Journ. Geol. Soc., vol. xxxvi, p. 284.
[4] Proc. Som. Arch. and Nat. Hist. Soc., vol. xlvi, p. 51 of reprint.

compared with the Upper Devonian series of North Devon the natural inference is that the southern area was one in which the process of deposition of sediment went on slowly.

This slowness of deposition is still more marked in the case of the Lower Culm, for if Dr. W. Hind is right in correlating the Posidonomya Beds and the Chert-beds with the Pendleside Series, there remains very little indeed to represent the Carboniferous Limestone Series; merely some dark shales which may be 50 or perhaps 100 feet thick.

Now if we assume that the whole area of sea-floor on which these deposits were successively formed was being more or less rapidly raised as a consequence of volcanic disturbance, and that submarine vents were opened from which lava and ashes were ejected, have we not a sufficient explanation of the facts? On a submarine area lying at some distance from land and undergoing upheaval only a small thickness of sediment could accumulate; in the vicinity of active volcanic vents animal life could not continually flourish on the sea-floor, and consequently limestones would either be thin and sporadic as in the Upper Devonian, or entirely absent as in the basal beds of the Culm.

In South Devon, therefore, it would seem that not only have we to accept the fact that there is very little to represent the Lower Carboniferous Series, but we are furnished with a good and sufficient reason for a fact which would otherwise be very difficult to explain.

Applying the lesson thus learnt in South Devon to the problem which has so long exercised the minds of geologists in North Devon, it is evident that we may have to accept as a fact the absence of any commensurate equivalent of the Carboniferous Limestone Series; for even if it should turn out that some part of the Pilton Beds are of Carboniferous age, yet it is not likely that any great thickness of such beds can come in between those which contain a Devonian fauna and the Fremington Beds.

It may be said that there is no evidence of volcanic activity in North Devon either during Upper Devonian or Lower Culm time. So far as we know at present there is little evidence of it, but there is intrusive felsite at Bittadon near the junction of the Morte Slates and the Pickwell Down Beds, and similar rock was traversed in the Button Wood cutting on the Barnstaple and Lynton Railway.[1] This felsite was described by Professor Bonney in 1871,[2] and regarded by him as probably of late Devonian age, but it may with equal probability be referred to the Lower Carboniferous, for, as Professor Bonney pointed out, the only clue to its age is the fact of its being cleaved, which proves the intrusion to be "prior to the close of the Carboniferous Period." Another dyke of intrusive igneous rock (apparently basalt) occurs in the Fremington Beds near Fremington, and Mr. Hamling informs me that it is not far from the passage to the Lower Culm; a little further south is a boss of grey felspathic rock, the relations of which are more obscure.

[1] Summary of Prog. Geol. Survey for 1897.
[2] Geol. Mag., Dec. II, Vol. V, p. 207.

But even if there were no active vents in the northern area we must remember that the distance between the two areas is not great. The tract of Lower Culm at and near Bampton is only 24 miles north of Ashton, and Coddon Hill is only about the same distance from the northern border of Dartmoor, so that if the southern area was being elevated and shallowed the northern area could hardly fail to partake in the upward movement to some extent.

The great thickness of the Upper Devonian in North Devon does indeed seem to indicate that no upward movement was in progress there during the process of its formation, and in this connection we must remember that we have no proof of upheaval at this time in South Devon, only the association of volcanic rocks. The actual uplift may not have taken place until the beginning of Carboniferous time, for it is only in the Lower Culm that evidence of erosion occurs, and it is the Lower Carboniferous rocks which are apparently so thin both in South and North Devon.

The probability of the suggested upheaval and erosion in South Devon is increased by the fact that in Brittany (still further south) there is a decided break between the Devonian and the Carboniferous. In that region the oldest Carboniferous rocks are conglomerates, sandstones, and volcanic rocks, which lie unconformably upon the Middle Devonian, both in the basin of Chateaulin and in that of Laval. These are succeeded by slates with occasional limestones, which seem to represent the Visean or upper part of our Limestone Series.[1]

In conclusion, I may observe that I should not regard the existence of Radiolaria in the chert-beds as constituting a difficulty in the way of my suggestion, for I dissent from the view that Radiolarian cherts are by themselves any proof of deep water. Mr. L. Cayeux has shown that siliceous deposits containing Radiolaria occur in the Oxfordian of the Ardennes, in the Gaize de l'Argonne, in the Smectique de Herve (Belgium), and in the Lower Eocene tuffeaux of France and Belgium. None of these can be regarded as specially deep-water deposits, while the last occurs in sands of the age of our Thanet Beds, and yet is very rich in Radiolaria.[2]

It is evident from these facts that other proofs than the mere occurrence of Radiolaria are required before the supposition of very deep water or oceanic conditions can be accepted. Such proofs are not forthcoming in the case of the Culm chert-beds, for, as I have remarked elsewhere,[3] the beds associated with them are not comparable in any way to the oceanic deposits of the present day. So far as we can judge, Radiolarian deposits are more indicative of conditions which do not favour the existence or the preservation of the remains of calcareous organisms than of any special depth of water.

Finally, the fact of the occurrence of similar cherts containing

[1] See de Lapparent's Traité de Géologie, 4th ed., p. 895, and references.

[2] Contrib. à l'étude micro. des terr. sédim.: Mem. Soc. Géol. Nord, tom. iv, Lille, 1897.

[3] Stratigraphical Geology, p. 269, Stanford (1901).

Radiolaria in South Wales between the Carboniferous Limestone and the Millstone Grit proves that conditions suitable for their formation occurred at no great distance from Carboniferous land, and goes far to disprove the view put forward by Messrs. Hinde and Fox that the Lower Culm beds of Devonshire are "deep-water representatives of the shallower-formed calcareous deposits to the north of them." [1]

## III.—A Wind-worn Pebble in Boulder Clay.

By Dr. F. A. Bather, M.A., F.G.S., British Museum (Natural History).

NEARLY forty years ago Mr. R. D. Darbishire obtained from the Glacial gravel of Bowdon, Cheshire, a facetted pebble, which I afterwards had the privilege of describing (Proc. Geol. Assoc., xvi, pp. 396–420, pl. xi, June, 1900). The conclusion then reached was that the pebble bore witness to the action of blown sand at a period during or not long before the deposition of that particular bed of Glacial Drift. Since, however, the pebble was in other respects similar to pebbles common in the Bunter beds, and since some had supposed the existence of desert conditions in those Triassic times, there remained the possibility, and to some minds the probability, that the pebble in question had received its facets during the Triassic epoch. It may, therefore, be useful to draw attention to a distinctly facetted pebble from the Boulder Clay within twenty-five miles of Bowdon. This was found by Mr. W. D. Brown, of Burscough (north-west of Ormskirk, Lancashire), at about three feet below the surface in the Burscough Brick Company's clay pit. The pebble is composed of a greyish micaceous sandstone, weathering yellow, and too coarse and loose in texture to be capable of taking a polish. The facets on it, however, are clearly cut, and do not appear to have undergone much, if any, subsequent abrasion. Its greatest length is 37·5 mm.; greatest width, 29·5 mm.; greatest thickness, 7·9 mm. What was probably its uppermost surface, during the latest period of its exposure to wind action, shows a flat central area, of irregularly pentagonal outline, surrounded by five facets, of which one is slightly concave, one rather irregular, two slightly convex, and the last markedly convex and probably retaining the original curved surface of the pebble. The greater part of the under side seems to preserve the original rounded, presumably water-worn, shape, but about two-thirds of this side is bevelled at an angle of about 45° by two facets which are not clearly separated from one another. The number of facets on the upper side suggests that the stone was, perhaps more than once, shifted round its vertical axis, while the under side indicates that it was at one time blown over into a different position of equilibrium. Nothing, however, would be gained by further speculation: the real value of the find seems to lie in its confirmation of the view that abrasion by blown sand did take place in the north-west of England during the later Glacial age. Mr. Brown tells me that he found another facetted

[1] Quart. Journ. Geol. Soc., vol. li, p. 609 (1895).

pebble in the clay of the same pit. Possibly, therefore, wind action was not rare; its traces may even prove sufficiently common to warrant the inference that steppe-like conditions then extended to those parts of the country. The other evidence in favour of that view need not be repeated here; but it should be borne in mind, for, as pointed out in my previous paper (p. 415), what is good proof of wind abrasion is not in itself a necessary proof of steppe or desert conditions.

The pebble herein described remains in Mr. Brown's collection, but he has kindly allowed the Geological Department of the British Museum to take plaster casts of it. For this, and for his courtesy in submitting the specimen to me, he has my sincere thanks.

## IV.—The Rhodesian Banket Beds.

By F. P. Mennell, F.G.S., Curator of the Rhodesia Museum, Bulawayo.

### I. *Introduction.*

WHAT are popularly termed the Banket Beds of Johannesburg have for years past been justly celebrated for their extraordinarily large and steady gold production. Their literature has already assumed formidable dimensions, so it is unnecessary for my present purpose to give a detailed account of the features they present. They form part of what is generally known as the Witwatersrand Series, which consists of highly altered sandstones and conglomerates almost certainly of Archæan age.[1] They unconformably overlie the banded rocks known as the Hospital Hill Beds, and are overlain by the Dolomite, often termed the 'Olifants Klip' or 'Elephant Rock.'

The gold in the Rand banket is not found in independent veins or reefs. It is confined to a few more or less constant horizons (universally but erroneously termed 'reefs') in the rock itself, but at the same time the latter is highly impregnated with silica and pyrites, and it is these cementing materials, principally the pyrites, which carry the gold, while the pebbles are practically non-auriferous. It thus appears that the absence of true veins is due to the ease with which solutions could spread through the originally incoherent gravelly material, instead of their flow being confined to cracks and fissures. The constancy of horizon may therefore be attributed merely to the localization of precipitants. It is certainly not due to the gold being detrital like the other materials of the rock: regarded as ore deposits the Rand veinstones are in no sense 'alluvial.'

### II. *The Old Rhodesian Conglomerates.*

I first drew attention to the occurrence of conglomerates among the presumably Archæan rocks round Bulawayo in the Rhodesia

[1] See discussion of age and correlation, Geol. S. Rhodesia, pp. 20–25.

Museum Report for 1902. Since then further investigation has shown how widespread is their distribution throughout the country, and has yielded much evidence as to their origin, lithological characters, and stratigraphical position, the discovery of gold in the Lomagundi district having been instrumental in promoting an active search for the rock in nearly all the mining districts.

In view of the fact that specimens have been submitted to experts outside the country, who have been disposed to favour the idea that the rock is a 'crush-conglomerate' rather than an altered sediment, it may be as well to at once state the evidence against such a view. The internal evidence of even a good series of specimens is quite sufficient to negative the idea, while no one fully acquainted with the geological features of Rhodesia would ever have given it consideration.

As an Archæan rock, the conglomerate has undergone a considerable amount of alteration. It exhibits the results of shearing and crushing to a marked degree, as well as changes due to the infiltration of secondary minerals. But at the same time its original features are by no means unrecognisable. Thus we find that there is no grading of the pebbles into the surrounding matrix: in spite of crushing and slips they show perfectly well-defined boundaries even in sections under the microscope. More than this, they exhibit the greatest variety of rock types, and often, one may say as a rule, the common types of pebble are quite different in composition to the matrix. Thus, even where quartz and granite fragments are predominant, there is often no quartz in the finer material. There are frequently scarcely any representatives of the surrounding rocks among the pebbles, which comprise on the other hand petrological types nowhere known in Rhodesia at the present day *in situ*. I may instance the fact that a few yards of outcrop near Hopefountain yielded me on a hurried visit the following varieties of pebble: white glassy quartz, dark quartz, banded ironstone, 'halleflinta,' two kinds of chlorite schist, hornblende schist, granite, granophyre, porphyrite, and at least two distinct kinds of amygdaloidal lava. It will be evident from this that the crush theory is by no means strengthened even by such a supposition as the entire breaking down of an igneous intrusion. But it is the stratigraphical evidence which is decisive, and it is unnecessary to dwell on the points already raised in view of the distribution of the conglomerate over the entire country, taken together with its great thickness and its position being always reconcileable with its occupying a constant horizon. The rock is, in fine, precisely what one would expect to result from the denudation of an extensive area of varied igneous and metamorphic rocks. Hard and resistant substances like vein quartz, banded ironstone, granophyre, and halleflinta form most of the pebbles, while the more easily disintegrated granites and schists have usually gone to make up the finer matrix. The ready decomposition of the more basic igneous rocks and hornblende or chlorite schists affords an obvious explanation of the cases where the pebbles are largely quartz, with some granite or granophyre, in a matrix now converted

by metamorphism into hornblendic or chloritic schist. And crushing as a mode of formation is obviously inconceivable in the cases, by no means uncommon, where numerous chlorite-schist pebbles occur in a sandy matrix.

### III. *Stratigraphical Position.*

In discussing its origin I have already remarked on the constant horizon of the conglomerate. It is the topmost member of the Rhodesian Archæan group, which comprises—

(3) Conglomerate and grits.
(2) Banded ironstone.
(1) Crystalline schists.

The last include the oldest rocks, but also a certain number of recrystallized masses which represent relatively late igneous intrusions. The three groups are unconformable, though they usually exhibit a concordant strike and dip. These, however, are obviously more apparent than real, the dip being that of foliation or cleavage. The banded ironstones, it may be as well to mention, are an enormously thick series of altered sediments, sometimes, though rarely, slaty, but more often highly silicified and jaspery, or consisting almost entirely of limonite, hæmatite, or magnetite. The banding, which is probably a very unsafe indication of bedding, is, however, always to be seen, an alternation of red and white, brown and white, or other dark and light bands being conspicuous in most cases. These rocks are known as Griquatown Beds in Cape Colony and Hospital Hill Beds on the Rand, in which latter locality they unconformably underlie the famous banket. Our conglomerate has thus precisely the same stratigraphical position: it unconformably overlies the banded ironstone and is implicated in most of the later movements of that rock, a corresponding foliation having been impressed upon it. The great granite masses of Rhodesia are intrusive in all the rocks up to and including the conglomerate, and some of the epidiorites, in which the granites are themselves intrusive, are almost certainly the result of the alteration of doleritic intrusions also later than the conglomerate. In any case the conglomerate contains no pebbles derived from them. I think the probabilities—and these are all we have to go upon in any South African correlations—are extremely strong in favour of the Rhodesian conglomerate being the stratigraphical equivalent of the Witwatersrand Beds.

As regards distribution, the only districts where the conglomerate has yet been continuously traced over a large area are those of Bulawayo and Lomagundi. It is, however, known to occur in the Umtali, Abercorn, Mazoe, Hartley, Sebakwe, Selukwe, Victoria, Belingwe, Bubi, and Gwanda districts, that is to say, scattered over an area of fully 100,000 square miles. The thickness of the rock and the associated finer sediments is very variable. Near Bulawayo it is from a few hundred to several thousand feet thick, and it is probable that the average is at least 1,000 feet.

### IV. *Economic Importance.*

The geological correspondence of the Rhodesian conglomerates with those of the Rand naturally raises the question of their proving of similar economic importance. As a matter of fact, though it has not been generally recognised, 'banket' has been worked for some time on the Wanderer Mine at Selukwe, a big low-grade deposit at the junction of the conglomerate and the banded ironstone, the latter, however, forming the bulk of the ore. The conglomerate has been tested in numerous other localities, with poor results, and so far it is only at the Eldorado Mine in the Lomagundi district that gold has been proved to exist in payable amount. Recent developments at this locality have shown that not only is the ore in general of very high grade, but that the ore shoot contains occasional patches of phenomenal richness. The conglomerate is here altered and sheared to a greater extent than usual. The matrix has passed into the condition of hornblende schist, and consists of deep-green ragged hornblendes, irregular felspar granules, and some possibly secondary quartz; epidote, biotite, and chlorite being also present in addition to magnetite and pyrites. The pebbles, which are occasionally large enough to be termed boulders, are chiefly of granite or granophyre, considerably altered, but not so much so as to leave any doubt as to their nature. Nearly black quartz is common, and what may possibly be banded ironstone also occurs. Pebbles of white quartz are rare, but many little veins of secondary quartz are seen, sometimes traversing faulted pebbles in a most interesting manner, while there is often a good deal of pyrites. The rich specimens enable the distribution of the gold to be studied with unusual ease. The precious metal is practically confined to the matrix of the conglomerate, and is principally seen in cracks formed after it had assumed its present characters, apart of course from those due to changes resulting from the introduction of the gold itself and that of the other secondary minerals by which it is accompanied. Even where very rich the gold is fine and not nuggety; it is rarely seen in the pebbles. When they do show it, it is always along cracks formed during the extension of the pebbles at right angles to the pressure, or along slipping planes, sometimes with and sometimes without secondary quartz and pyrites. Round the pebbles, and especially at their ends, where slips would tend most to loosen the rock, the gold is often very abundant, forming a regular coating to the pebbles in extreme instances. It is clear that here, as on the Rand, the gold is of secondary origin, and was not present during the original deposition of the rock.

I may conclude by expressing my indebtedness to Dr. H. Sauer for specimens, etc., and for permission to describe the Eldorado rock; to Messrs. J. L. Popham and A. J. C. Molyneux, F.G.S., for specimens and slides; and to Mr. H. E. Jones, A.R.S.M., for some valuable notes and suggestions.

## V.—Contributions to the Geology of Ceylon:

## 4. Intrusive Pyroxenites, Mica-pyroxenites, and Mica-rocks in the Charnockite Series or Granulites in Ceylon.

By Ananda K. Coomáraswámy, B.Sc., F.L.S., F.G.S., Director of the Mineralogical Survey of Ceylon.

(PLATE XX, IN TEXT.)

THE object of the present paper is to provide a short account of a group of rocks to which the general name of *pyroxenite* may be given, inasmuch as they are essentially non-felspathic plutonic rocks, free from olivine, and of igneous origin, and with a nearly colourless monoclinic pyroxene as the chief or only constituent of many of the most conspicuous varieties.[1] The exposures are widely distributed in the Central, Uva, and Sabaragamuwa provinces, and probably throughout Ceylon, but are individually of very small extent. The rocks are composed of the minerals diopside, amphibole, phlogopite (or biotite), scapolite, pyrite, sphene, and sometimes felspar, calcite, and spinel; the dominant mineral is the pale green or grey granular diopside, colourless in thin sections: the rocks are often entirely, or almost entirely, composed of this mineral; next in importance are green amphibole (dark in hand-specimens, but very pale in thin sections), and a pale golden-brown phlogopite, which sometimes forms a large proportion of the rock, and in extreme cases the whole bulk of sills or dykes several feet in thickness.

The rocks occur in sills and dykes of all sizes, from a fraction of an inch to six feet or more in thickness, and their intrusive character is generally clear. Very similar or identical rocks occur also as nodular aggregates in crystalline limestones, and also near and along junctions of granulite and crystalline limestone[2]; but for the sake of brevity and clearness, only those occurrences which are less particularly associated with the crystalline limestones are described in the present paper. The pyroxenites are clearly intrusive in the charnockites or granulites; although often occurring in beds or sills following the foliation planes of the granulites, they occur equally or more often as typical dykes crossing these foliation planes, and sometimes occupying joints; the figures illustrate examples of both modes of occurrence, which, moreover, are frequently associated.

This occupation of joints shows that the pyroxenic material must have been introduced after the granulites had sufficiently consolidated to allow of the formation of joints. This fact, together with another, viz., the occurrence of what seems to be a very ordinary mica pyroxene dyke cutting the zircon granite (itself belonging to the Balangoda group,[3] and forming an intrusive sill in

[1] For a discussion of the nomenclature of similar rocks, see C. H. Gordon "On the Pyroxenites of the Grenville Series in Ottawa County, Canada," Journal of Geology, vol. xii, No. 4, 1904, pp. 324, 325.

[2] For descriptions see A. K. Coomáraswámy, "The Crystalline Limestones of Ceylon," Quart. Journ. Geol. Soc., 1902, vol. lviii, pp. 399–422.

[3] A. K. Coomáraswámy, Geol. Mag., No. 482 (1904), pp. 418–422.

the Charnockite Series or granulites) of Massena estate, Balangoda, appears to indicate that the date of the pyroxenite intrusions was long posterior to that of the intrusion and consolidation of the granulites. Nevertheless, careful examination of the junctions shows that there is never any sign of a chilled edge, but the pyroxenic rock passes, rapidly indeed, but never abruptly, into the granulitic rock next to it, and this even where the intrusive character is otherwise most distinct. There is, in fact, a rapid transition from one rock to the other. Inasmuch as the pyroxenites are intrusive in rocks which had cooled sufficiently to allow of the formation of joints, these facts seem to show that re-melting must have taken place to some extent.

A zoned structure is very characteristic of the rocks, the zoning being marked by the distribution of mica in bands parallel to the edges of the dyke or sill, the individual crystals of mica being disposed in planes perpendicular to the edges of the dyke or sill, which is often symmetrical in structure about a median line, after the manner of mineral veins. The zoned structure is not always produced by mica; in Fig. III, Pl. XX, p. 366, for example, the central darker zone is distinguished by its content of hornblende, and mica is not present.

The pyroxenites seem to be in some way connected both in mineral composition and in actual distribution with the occurrence of crystalline limestones, though the exact relation is not perfectly clear. One curious feature is the presence of carbonates in parts of the dykes, especially at Ella (Uva) and Kadawat Oya (Sab.); when it becomes abundant, the central zone is sometimes indistinguishable from an ordinary crystalline limestone with abundant accessory minerals.

A more detailed account of various exposures (especially those illustrated) will now be given; the localities described have been visited at various times during the last two years.

1. At Ella (Uva) are interesting exposures (Fig. I, Pl. XX, p. 366) in the bed of the Kitul Ela, just below the point at which it is joined by the small stream from near the Rest House. The main part of the intrusive rock consists almost entirely of granular greyish-green diopside (1152);[1] in parts scapolite and a little granular sphene are also present, and more locally hornblende or mica. A section (1153) through the junction with granulite at the point X in the figure shows granulite (a rock composed of quartz and orthoclase with a little pale-green diopside) passing very rapidly but with no loss of continuity into a granular rock consisting of colourless diopside with scapolite and a few rounded grains of sphene. At one point in the exposure a large crystal of diopside projects from the pyroxenite into the granulite, merely an exaggeration of the usual interlocking of minerals at the junction. The inner portion of the pyroxenite (at *h*) becomes rich in carbonates, and the relation to the rather impure granulites at *g*[1]

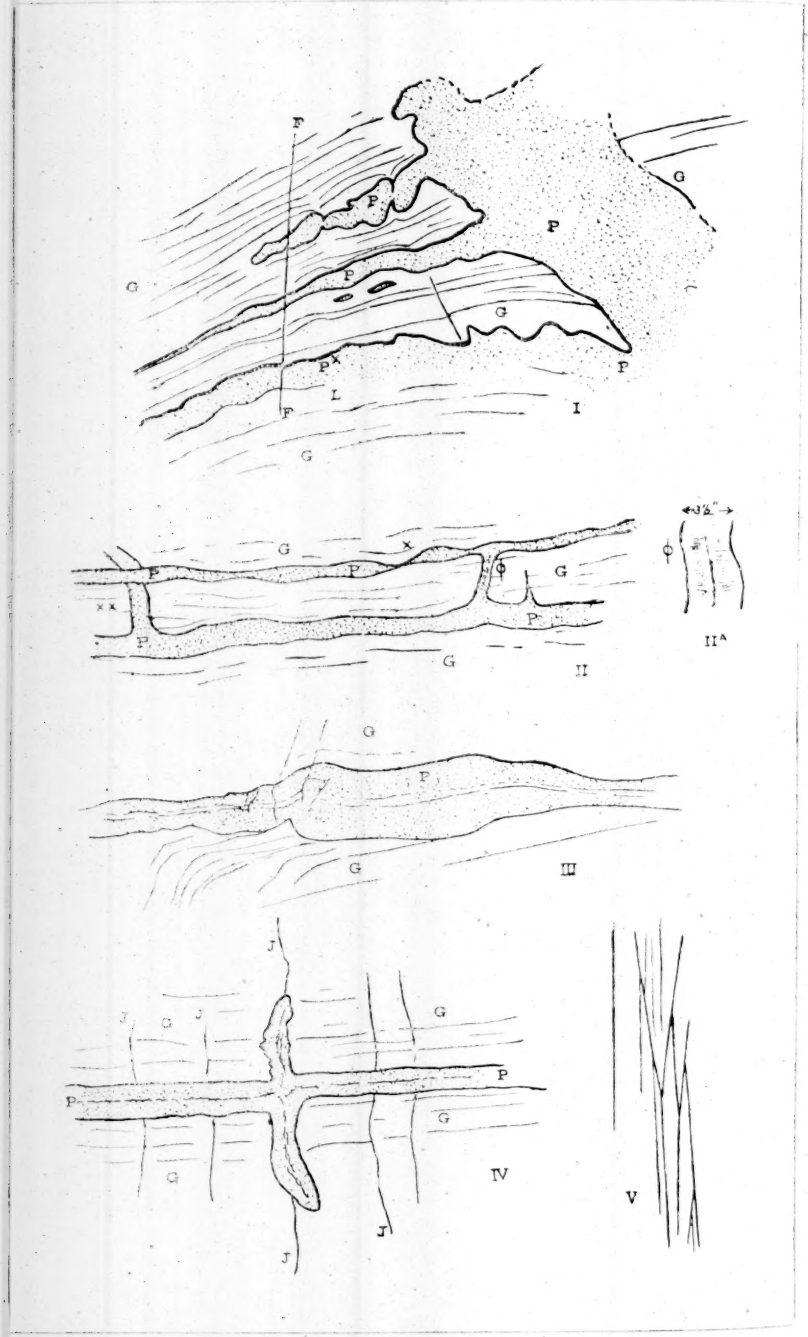
[1] The numbers in brackets refer to thin sections in the author's collection.

is not quite clear. The bands of intrusive pyroxenite following the granulite foliation planes tend to pass into lenticles, as if by a process of pinching, the lenticular forms being exactly followed by the granulite foliation planes; this fact, and the junction phenomena, makes it seem likely that the granulites were not in a completely consolidated state when the pyroxenic material was introduced. Similar 'pinching' is shown in Fig. II, Pl. XX, p. 366, at X.

2. In the bed of the Talatu Oya at Uduwela, near Kandy, there are several exposures of pyroxenic rock. Fig. II shows sills of pyroxenite (nearly pinched out at X) combined with dykes along joint planes. A section (1067) of the junction at X shows the intrusive rock to consist internally of an aggregate of colourless diopside with a peripheral hornblendic zone passing into the granulite, in which plagioclase and diopside are the dominant minerals, and pyrite is also common. A section (1069) of the pyroxene further from the edge shows only colourless diopside with a trace of plagioclase and green spinel. A junction section (1068) at $\phi$ (Fig. II) showed orthoclase diopside rock (granulite) passing into a diopside plagioclase rock (pyroxenite) with accessory pyrite, sphene, and apatite. The (subordinate) plagioclase has an ophitic habit, enclosing more than one individual of diopside, which is also intergrown with it in radiating root-like fashion. In the central part of the dyke mica becomes abundant, and is arranged in planes perpendicular to the edges of the dyke, as indicated in Fig. IIA, Pl. XX, p. 366. One other slide (1066) from the place marked XX shows an aggregate of diopside and amphibole with a little accessory pyrite.

Some smaller dykes at Uduwela are very micaceous; a section (1149) of one about an inch wide shows granulite (quartz-orthoclase-plagioclase rock with a little diopside) passing successively into diopside rock with a little plagioclase, diopside rock, and diopside-mica rock. The mica is in hand-specimens the most conspicuous mineral, and is arranged in planes perpendicular to the edges of the dykes.

3. Fig. III shows a zoned pyroxenite dyke cutting the foliation of the Charnockite Series, exposed in the bed of a stream entering the Badulla Oya from its right bank, about 8½ miles from Badulla and near Nanla. The outermost zone (about 3 inches wide) shows under the microscope (1147) a compact intergrowth of colourless diopside (partly also in granular forms) with subordinate plagioclase. The diopside intergrown with plagioclase exhibits root-like forms, and the intergrowth is on a very fine scale, so that the plagioclase is not easily recognizable. The central one or two inches of the dyke are clearly marked by the presence of dark hornblende, which in the hand-specimen can be seen moulded on idiomorphic grey-green diopside in ophitic wire. In the thin section (1148) the hornblende appears pale bluish green, with pleochroism a pale straw, b bluish-green with a brown tinge, and c bluish-green. This is the usual amphibole characteristics of the rocks now described.




Intrusive Pyroxenites in the Ceylon Granulites.

In illustration of Mr. Coomáraswámy's paper.

4. There are good exposures of pyroxenites at Kadawat Oya bridge, between Belihul Oya and Halpe (near the 99½ mile-post), Sabaragamuwa. A number of pyroxenic sills and dykes occur, and very heavy hornblendic and pyritic types are characteristic. The dykes vary from mere threads up to 1½ yards in width. Some show very clearly penetration of the pyroxenic material along joints (Fig. IV). Several dykes have quite narrow central zones, consisting mainly of pyrite; in one case large individuals of pyrite occurred at intervals along this line. Some of the larger dykes have central portions composed largely of carbonates with abundant accessory minerals (amphibole, phlogopite, spinel).

A section (1122) from the point marked X in Fig. IV shows a rock consisting almost entirely of pale sea-green diopside with a very little pyrite, apatite, and phlogopite; the diopside has a very carious structure, the cavities being occupied by semi-ophitic plagioclase. The whole dyke is about 6″ wide. A section (1123) of another dyke, 6″–8″ wide, proves it to consist mainly of very pale sea-green diopside, with some strongly pleochroic phlogopite, yellowish-green amphibole, green spinel, pyrite, apatite, and calcite. The diopside tends to granular forms, moulded by the mica and spinel, the latter being apparently almost the last formed mineral, occupying interstices amongst the grains of pyroxene. As the junction with granulite is approached the mica dies out, and some felspar and pink garnet come in. One other dyke, very dark in colour, consisted mainly of hornblende (especially in the central zone), pale bluish green in thin section (1150), and diopside with a trace of plagioclase occupying interstices; the hornblende has a strong tendency to crystalline form, even when in contact with diopside (a reverse relation is found in the central zone of the dyke shown in Fig. III, Pl. XX, p. 366, see description above).

5. 'Thread dykes' and others slightly wider. These very narrow dykes appear as dark lines crossing foliation on the surface of rock exposures (Fig. V). Under the microscope there appears nothing more than a rapid concentration of hornblende along a zone perhaps ½ inch wide (1103). These very narrow dykes are often in more or less parallel groups of two or three (Fig. V); sometimes they intersect at acute angles. Occasionally they widen out into dykes an inch or more wide, clearly visible in the field, but with such indefinite margins as to be hardly recognizable in hand-specimens.

A few additional examples may be briefly referred to.

6. A sill of grey-green pyroxenic rock 6–8 feet thick is exposed in the river bed below the road, about 10½ miles from Badulla on the Bandarawela road. The rock (1109) is a coarse aggregate of diopside and scapolite with scattered idiomorphic sphenes; other varieties consist practically entirely of diopside, individuals of which reach ¾ inch in width. The rock is very tough. Somewhat similar rocks are found, not quite *in situ*, on the slope below the 69th mile-post on the Badulla Nuwara Eliya road, and some of these are very handsome coarse aggregates of diopside, amphibole, and scapolite, with calcite and idiomorphic sphene (often over ⅛ inch

long). The magnesian silicates and scapolite are idiomorphic towards the calcite and present a handsome appearance in weathered specimens.

In the Uma Oya below there are numerous exposures, both of 'thread dykes' and of intrusive pyroxenic and micaceous rocks, as well as of coarse felspathic pegmatites, with which their relations are somewhat confused.

7. Of pure mica rocks or veins there may be instanced those described in the (first) "Administration Report of the Mineralogical Survey," Colombo, 1904. Analyses of mica will be found in Professor W. R. Dunstan's "Reports on the Results of the Mineral Survey [of Ceylon] in 1903–4," London, 1905.

One example of a mica rock or vein may be quoted from the (second) "Administration Report of the Mineralogical Survey," Colombo, 1905, p. 20. A large vein of brown phlogopite is exposed in the Mineran Oya, just within the boundary of Sherwood estate (about nine miles north of Balangoda), in the south-west corner. The vein is about 5 feet wide, and strikes 20° N. of E. and hades 70° S.S.E., and crosses the foliation of the granulites, which are inclined at low angles. The Oya has for some distance cut its way along the mica vein, which is exposed in the bed of the stream. The largest crystals are 18 inches in diameter, but somewhat flawed.

8. A fairly typical zoned mica pyroxene dyke, from 2 inches to 1 foot wide, is found cutting the zircon granite (Balangoda group) of Massena estate, Balangoda. As the zircon granites are themselves intrusive in the granulites,[1] the pyroxenic intrusions would thus appear to be removed from the date of intrusion of the material composing the Charnockite Series, by the period required for the intrusion of the Balangoda group.

*Canadian analogies.* The rocks described closely resemble the pyroxenic rocks associated with the apatite deposits of Canada, described by A. Osann ("Notes on certain Archean Rocks of the Ottawa Valley," Geol. Surv. Canada, part O, Ann. Rep., vol. xii, 1902), and by C. H. Gordon ("Pyroxenites of the Grenville Series in Ottawa County, Canada," Journal of Geology, vol. xii, No. 4, 1903, pp. 316–325), who states that the evidence there too "clearly warrants the conclusion that the pyroxenic rock is intrusive." Detailed descriptions and further references will be found in the papers mentioned.

*Summary.* A group of pyroxenites, in which the minerals diopside, phlogopite, hornblende, and scapolite predominate, while sphene, plagioclase, pyrite, apatite, and spinel are often accessory, occurs in small sills and dykes intrusive in the Charnockite Series or granulites, and in one case apparently also in a zircon granite of the Balangoda group. The pyroxenic intrusions have usually a zoned or laterally symmetrical structure analogous to that of mineral veins. The intrusive material never shows a chilled edge,

[1] A. K. Coomáraswámy, "The Balangoda Group": Geol. Mag., 1904, pp. 418–422.

but there is a rapid transition from the pyroxenite to the granulite. The course of the small sills and dykes of intrusive pyroxenic material is usually determined by the foliation planes and joints of the granulites or Charnockite Series.

EXPLANATION OF PAGE-ILLUSTRATION, PLATE XX (p. 366).

INTRUSIVE PYROXENITES IN THE CEYLON GRANULITES.

FIG. 1.—Intrusive pyroxenite at Ella (Uva); area shown about 6 × 4 yards. P, pyroxenite; G, granulite; F, fault.

,, 2.—Pyroxenite sills and dykes, Uduwela (Central Prov.); length shown about 8 yards. P, pyroxenite; G, granulite.

,, 3.—Pyroxenite dyke with well-marked symmetrical structure, exposed in feeder of Badulla Oya, near Naula; average thickness, 6 inches. P, pyroxenite; G, granulite.

,, 4.—Intrusive pyroxenite following foliation planes and joints in granulites (also in Figs. 1 and 2), Kadawat Oya bridge (Sab.); thickness, 6 inches. P, pyroxenite; G, granulite; J J, joints.

,, 5.—'Thread dykes,' exposed in feeder of Badulla Oya, near Naula; average thickness, ¼ inch.

KANDY, *June* 19, 1905.

## VI.—GOLD AT KNYSNA AND PRINCE ALBERT, CAPE COLONY.

By ERNEST H. L. SCHWARZ, A.R.C.S., F.G.S.,
Rhodes University College, Grahamstown, Cape Colony.

IN 1895 the author visited the Prince Albert Goldfields, and later the Millwood Goldfields in Knysna, and has had the subject constantly before him till quite recently, when, in reviewing the whole question in connection with the geology of the region, which he has now worked out under the auspices of the Geological Commission of the Colony of the Cape of Good Hope, he was able to come to some definite conclusions. The gradual building up of convictions on a subject like this, as facts became clearer with increased knowledge derived from the reports of prospectors, the progress of the Survey, and the access to literature bearing on kindred questions, led to the acceptance of certain general principles, which the author has thought worth while to state in definite form for criticism. The peculiar points in the occurrence of the precious metal in these localities cause them to rank high as fields for research, if not for general enrichment of the inhabitants of the Cape Colony.

The Millwood fields lie in the Outeniqua Mountains, shut off on the north by high grass-covered ridges with many picturesque peaks, rising to heights of about 4,000 feet, on the south by lower hills covered with dense forest. The Outeniqua Mountains form the first of a series of parallel chains that screen the Karroo from the coast, and on the seaward side there is but a narrow coastal ledge separating the foot-hills from the shore of the Southern or Indian Ocean. The rainfall is abundant, but subjected to periods of drought lasting from three to four months; on the whole, however, one can say that there is a heavy shower once a week. The ground about the goldfields is all on a steep slope, and storm-water

rushes off with great vehemence, but the covering of grass which the hills possess retains a certain amount, which is in part returned to the surface by springs.

The Prince Albert Goldfields, on the other hand, lie out in the very heart of the dry country, where droughts last eighteen months and more; where the rain comes with thunder-clouds, perhaps a dozen times in good years during a twelvemonth, and then lasts but an hour or so. The country is kopje veldt, that is, cut into innumerable little hillocks of bare rock on which the scanty Karroo bushes thrive. The roots of these woody plants penetrate into the cracks in the shales and sandstones, and carry down soil with them in the crevices, but there is no covering of soil on the surface. The streams are very steep-graded, and even along the large rivers there are very scanty patches of alluvial soil. Denudation is mostly affected by changes of temperature, which reduces the rocks to small fragments; these are then further reduced by wind, which rolls them about, and finally carries them away in small particles. The rains are so tremendous, when they do fall, that the ground is covered with a continuous sheet of water, hill and valley alike, but only for a few minutes; before the sun can come out again this mass of water is tearing down the runnels into the main channels, and roaring its way to the sea.

### *The Millwood Area.*

The coast range of mountains west of this place can be stated generally to consist of an S-shaped fold of Table Mountain Sandstone, the anticline occupying the north side and the syncline the south. The northern limb of the anticline dips under Bokkeveld Slate, containing fossils of an American type, belonging to the Lower Devonian; the syncline rests on pre-Cape rocks, Malmesbury Beds injected with granite, probably of very ancient age. This fold is reduplicated in several places, and subsidiary folds become added to the main syncline and anticline. At Mussel Bay and George there is an immense boss of granite, against which the folds are huddled on the north side, so that syncline and anticline are pressed together, and all the strata dip south. The granite is somewhat different from the main mass which exists in the south-west of the Colony, as it is a white mica granite; towards the eastern end of the boss the rock has been sheared, and later injections of tourmaline granite have filled in the spaces produced by the movement. At the end of the granite there is a tract of slates, and then another great mass of granite. The two bosses are connected by a dyke which traverses the slates, which at one point suddenly changes its strike from N.E. to E.N.E. The substance of the eastern granite appears not to have been sheared like the end of the other boss, and I am inclined to believe that this is not a true boss, anchored to the basement granite of the south-western districts, but is an immense lateral offshoot injected horizontally into the slates. The crush which buckled up the mountains, coming from the north, was brought up against the main granite mass, but where this ended the

thrust sheared the termination and deflected the great arm of granite seawards.

Where the granite ends the whole nature of the rocks of the mountains changes; no longer have we miles of strata on end, as near George, but the folds widen out, and dips of 10° to 15° prevail. West of this point the dips are south all through the mountain ranges; east of this point there are both north and south dips; in other words, the folds are upright and open, instead of being pressed together, and inclined to the south.

The direction of the granite dykes is near here N.E., and then suddenly swings round to E.N.E., so in the strike of the Table Mountain Sandstone there is a sudden change from east and west to E.S.E. Any small scale map of South Africa will show distinctly

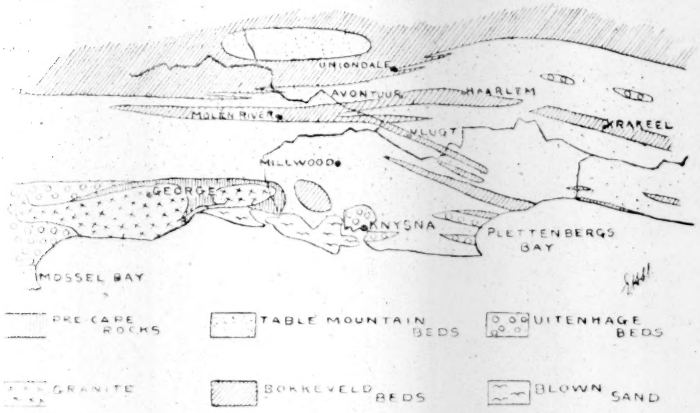



FIG. 1.—Map of the Coastal Plateau in George and Knysna, showing the bending of the strike round the end of the granite.

the streaming of the mountains round a point near George, and the recent survey of that part by the author showed that the cause of this change in the direction of the mountain chains was the termination of the granite. It is not till we get beyond the colony borders into Natal that we find granite again along the southern part.

It is in the angle of the bend in the Table Mountain Sandstone that the fissures occur which are now filled in with auriferous quartz. In between Millwood and the granite there is a syncline filled in with Bokkeveld Slates, and the quartz-reefs traverse the slate formation equally with the sandstone formation; but there are certain differences. In the slate the quartz-reefs are massive bodies of white veinstone, with a certain amount of pyrites and copper pyrites included in it; none of the reefs have yet been opened up properly, but they appear to be continuous over large areas and are constant with depth. They do not branch or break away from their general lie, which is parallel to the strike of the rocks, but with a dip somewhat greater. In the sandstone the veins are much less

constant, tending to pinch out and run into stringers, while the veinstone is often cased in a layer of silvery grey-green phyllite, which I take to be material that has been carried mechanically into the fissure before the quartz began to form from solution. The lie of the veins here also is along the strike of the rocks, and the dip generally is greater than the dip of the beds, but there is a good deal of variation in regard to the latter point.

The difference between the two modes of occurrence can be traced to the varying tensile strengths of the sandstones which go to form the Table Mountain Series: all grades of grain from gravel to the finest meal-sand occur in the beds, and in addition the coherence of the particles, due to cementing substances such as iron sulphides and silica, must be very different in the successive layers. In the Bokkeveld Beds, however, there is far more homogeneity in the texture of the beds, although when subjected to surface weathering there appears to be a good deal of variety; in the bulk, however, we can take the Bokkeveld Series to be made up of a continuous deposit of clay-slates, with occasionally a sandy or calcareous bed. North of the mountains great banks of quartzite appear, but to the south these have not been noticed, and it has been supposed that the beds along the coast represent sediments which have been laid down in deeper water than those to the north of the mountains.

The ore-deposits in the quartz-veins in the Table Mountain Sandstone area consist of gold, pyrites, galena, blende, and sometimes carbonate of iron. In the Bokkeveld area there are copper and iron pyrites. All these ores I take to have been deposited in the quartz-veins by lateral secretion, and not by the ascension of mineral solutions from great depths. By lateral secretion I do not mean to imply that the immediate walls of the veins have supplied the material, as argued by Sandberger, but that the rocks within a reasonable distance of the veins have done so, according to the broader views enunciated by Le Conte. At the same time I believe that there is an ascension of metallic substances in solution from the depths, only that here this explanation of the mineralization of the veins is out of the question, because the pre-Cape rocks underlying the Table Mountain Sandstone and in the immediate neighbourhood show no signs of quartz-veins bearing deposits of ore.

The vertical extent of the reefs is a question of great moment to the mining engineer, as upon the continuance of the reef depends the successful employment of capital. If the fissures are caused by an immense arm of granite, and not by a boss, then they will not go down into the earth to indefinite depths. We have reefs cropping out at 2,600 feet above sea-level in the Table Mountain Sandstone, and in the Bokkeveld Beds they are found at only a couple of hundred feet above sea-level. I consider it a low estimate if we take it that at least half of the distance of the mountains from sea-level upwards has been denuded away, and that the reefs originally extended to 5,000 feet above the present ocean surface. The reefs go at least 1,000 feet below the sea-level, for on the sides of the Little Homtini River we have a section showing a reef commencing

at 700 feet, and traversing the side of the ravine down to 200 feet, with every appearance of its continuing indefinitely.

I have shown reason to believe that the reefs represent fissures due to a tearing in the rocks as they bent round the end of the granite; they must, therefore, follow roughly a succession of shells of tension round the end of the granite arm, the actual course of the fissures being directed by the lie of the rocks, which would be stronger in one direction than in another, but the vertical extent, I think, would be independent of the formations, and the fissures traverse any kind of rock strata that may exist in the area of the shells of tension.

The Table Mountain Sandstone represents a shore deposit, and the Bokkeveld Slates a deeper-water formation. Taking into consideration the extent and distribution of these sediments, it is fairly well proved that they must be derived from a continent which formerly existed to the north of where they now lie. This continent we can see emerging from a later covering of Karroo rocks in Namaqualand, Prieska, and the Transvaal, and it contains deposits of minerals of exactly the kind which we find in Knysna, the O'Kiefs copper deposits and the Rand gold-banket, to take two instances. The detritus from this land would naturally carry with it a certain amount of the mineral ores, and they would be deposited along with the bulk of the sediments. There would be a rough sorting according to gravity, the heavier metals, such as gold, lead, and zinc, would tend to come to rest nearer the shore than the lighter ones, such as iron and copper, and I look to this action to explain the presence of the former group in the Table Mountain Sandstone and the latter in the Bokkeveld Slates.

In regard to the gold and associated metals, it is a well-known fact that sand does not tend to precipitate them, whether carried mechanically or in chemical solution, until the deposit becomes gravelly; and in the present case, although it is likely that traces of gold might be found in the sandstones on careful analysis, the major portion seems to have come to rest in a consolidated gravel or banket which occurs near the top of the series in this neighbourhood. Assays give 2 dwt. per ton of gold, and from its extreme hardness there is no possibility of mining this rock unless richer spots can be found. The banket dips under the Bokkeveld Slates, and comes up on the south sides of the inlier, so that it can be safely said to recur as a continuous sheet, dipping some two or three thousand feet below sea-level. In the Bokkeveld Slates pyritous layers occur, but as a general rule I think the ores of iron and copper were distributed fairly evenly throughout the mud that is now represented by the clay-slates: it partly impregnated them in the form of minute crystals and films, and in part has crystallized out in the form of cubes.

Having now traced the minerals from their original resting-place in the older rocks of the northern continent to the stratified deposits in Knysna, we have to follow the process by which they became leached out and redeposited in the quartz-veins. The circulation

of water through the substance of rocks is sufficiently recognised, and I think I need not labour the point that, if there are strata in compression and a series of opening cracks within reasonable distance, the water will pass from the one to the other.

With regard to the power of water to dissolve metallic substances, Doelter [1] found that pyrites, galena, antimonite, spherulite, arsenical pyrites, copper pyrites, and bournonite were to a certain extent soluble in pure water when heated for four weeks in glass tubes to a temperature of 80° C.,[1] and that pyrites, galena, zincblende, arsenical and copper pyrites, and bournonite were soluble in water containing sodium sulphide under the same conditions.[2] There is, therefore, no reason to suppose that enormous pressure or heat were necessary to make these minerals go into solution, and that they must have consequently come up from great depths; with the exception of blende the minerals are soluble in pure water, given moderate pressures and temperatures, such as would exist a few thousand feet below the surface, for it must be remembered that in dealing with these matters, where temperature and pressure are high in the laboratory experiments, the same results can be attained in nature by very much less temperatures and pressures, owing to the vast lengths of time in which the process has to act. In the case of zincblende an alkaline sulphide was found necessary to cause it to go into solution, and whether the particular sulphide, or, indeed, salt of whatever kind, was really present in nature, or some other, the main point proved in Doelter's experiment was that the zincblende could be made to go into solution.

With gold we have a much more refractory element, but a trace of free chlorine in the water would be sufficient to dissolve the gold from the banket. The surface-water of Millwood is tinged brown with organic acids derived from the roots of the grasses and sedge-like plants that cover the slopes of the hills; hydrochloric acid is present in minute quantities, and may be accompanied with free chlorine, so that the possibility of this solvent being present in the underground water is not entirely ruled out. Other solvents are sodium and potassium chloride,[3] sodium silicate,[4] sodium sulphide, sodium sulphydrate, and sodium carbonate saturated with sulphydric acid.[5] Le Conte and Wurtz have shown that ferric sulphate is also a solvent, and Atkin [6] has pointed out that this is by far the most likely of natural salts that cause the solution of gold.

Posepuy has argued that water circulating within a few hundred feet of the surface, and derived by absorption from the atmospheric water, would be an agent which oxidized the salts which it carried in solution, and therefore, if we accept his theory, the sulphides which colour the sandstones blue, would first yield a sulphate, and

[1] Tschermak's Mitth., 1889, vol. xi, p. 319.
[2] l.c., p. 323.
[3] Egleston: Trans. Amer. Inst. Min. Eng., 1880, vol. viii, p. 455.
[4] Liversidge: Proc. Roy. Soc. N.S. Wales, 1893, vol. xxvii, p. 303.
[5] Becker: Mon. U.S. Geol. Surv., 1888, vol. xiii, p. 433.
[6] Atkin: Q.J.G.S., 1904, vol. lx, p. 390.

the necessary solvent for the gold would be produced. But against this we have two undoubted facts in the area we are describing: the sandstones remain blue and have not the sulphides removed, even though we have very palpable evidence that Posepuy's vadose water is circulating through them; and, secondly, the Malmesbury or pre-Cape rocks in the neighbourhood, through which the deep-seated water would have had to pass to get to the mineral veins in the Table Mountain Sandstone, show no signs of having clefts or fissures which are filled in with ore and veinstone. The mineralizing water seems, therefore, to be undoubtedly that derived from the surface, and at the same time is not an oxidizing medium; if we are searching for a solvent, I think we should look to the ferric sulphide and not the sulphate as probably the active principle. The formation of ironstone gravel beneath the soil in so many places in the neighbourhood shows that the surface water does contain a very appreciable quantity of iron in solution.

Doelter has shown that the sulphide is soluble to a certain extent in pure water, and sodium sulphide is a solvent for gold; there are no sources which I can see whence a sodium salt could be derived, but it seems reasonable to suppose that the ferric salt might take its place. Until experiments have been carried out in this direction, it is naturally impossible to make the assertion that any one salt, if present in the water, would have dissolved the gold, but an enquiry like this may be useful to show chemists in what direction geologists want their help. I think, however, I have shown sufficiently clearly that gold will go into solution in water containing salts which naturally occur in the rocks, and that it is not necessary for the salt to be a compound of oxygen.

Whatever may have been the solvent, temperature and pressure would increase its action. Certain salts like sodium sulphate are more readily soluble with increasing temperatures and pressure up to a certain point, when there is a sudden decrease, while if there is a contraction in volume when the salt goes into solution, pressure and heat decrease the solubility.[1] These cases, however, are rare exceptions to the general rule that the rate of increase of solubility is a function of temperature and pressure, and it is a fairly safe statement that in the case of gold the rate of solubility is far greater 10,000 feet below the surface than it is at 1,000 feet. On this fact depends the question whether the reefs become richer with depth, and unless the gold behaves exceptionally with its solvent we may say that they do. The banket naturally, being a stratified deposit, would be unaltered with depth, but serving as a source of gold for the quartz-veins, and being near the cracks down to great depths, it is almost certain that there is increased solubility and consequent deposition of gold.

I therefore define the Millwood gold-reefs as true fissure veins, limited, however, in depth by the extent of the disturbance caused by the arm of granite, and filled in with veinstone and ore by

[1] Ostwald: Algemeine Chemie, pp. 1046, 1048.

lateral secretion; the process of leaching out the gold in the banket and depositing it in the reefs I term the second stage. The third stage is the displacement, mechanically or chemically, of the gold in the reefs and the building up or the deposition of gold nuggets in the alluvial gravels.

In this stage must also be included the surface enrichment of the reefs, caused by the concentration of the precious ores from portions of the reefs that have been removed by denudation. The quartz, being more homogeneous than the sandstones which it traverses, stands out somewhat from the surface when exposed to the influences of denudation, but it soon crumbles up, and the particles get washed down with the rest of the detritus; the gold, however, tends to stay where it is, owing to its great density. When the water which has slowly percolated through the rocks, and has taken up certain quantities of ferric sulphate, gets to the quartz-vein, it slowly dissolves the gold in it, and then becomes lodged in the vein, splintered by surface-weathering agencies. So, either by mechanical means or by chemical means, the surface of a quartz-reef tends to become far richer than it is in the bulk. Pieces of enriched surface-reef have been found so studded with gold that the poor prospectors thought that at last they had got the parent reef of all the alluvial, but no body of reef has been found carrying gold in appreciable nuggets.

The process that I have outlined to explain the surface enrichment of reefs is the same for the formation of gold nuggets. These are found in the alluvial gravels of the creeks, but especially in mud in the crevices in the sandstone and under great boulders, and are found in considerable quantity. There is no law enforcing registration of gold finds, and many thousands of pounds' worth of nuggets have been passed into the bank without notification, but, for all that, from the proclamation of the fields in 1887 to March, 1905, a total of 3,370 ounces has been registered. I was led to bring in the explanation that the nuggets must have in great part been built up from solution, and are not merely particles that have been washed out of the reefs by the following considerations:—

1. With the exception of a very few instances, no reefs have been found containing gold in nugget form.

2. The nuggets, running up to three and four ounces, are found in places where it would be difficult to explain their presence, that is to say, in narrow crevices and hollows surrounded with light sand. One would have to explain how these large nuggets got pushed past obstacles if we are to consider them as having been mechanically brought into place.

3. Many of the nuggets, although occurring in the stream-bed, show quite sharp ridges and points, so that they cannot have travelled very far, yet there is no source near at hand whence they could have been derived.

4. The creeks and gullies contain gravelly patches which are washed out and all the gold recovered; a few seasons later the same hollows are worked and the gravels are found to be as rich as before,

yet the whole of the creek sides have been closely and systematically searched in vain for reefs containing nugget gold. Unless the nuggets have grown in the place they are found in by deposition from solution, where can they have come from?

5. The solution theory accounts for all known facts. The solvent salt ferric sulphate as well as perhaps a little chlorine is present in the surface water; the gold would therefore be dissolved, and according as it was redeposited slowly by evaporation or instantaneously by reduction of the ferric to the ferrous sulphate, the nugget would be built up with sharp edges or in a rounded form.

Gold is found in fairly average quantity in gravel on an old river level called the Poverty Flats, and also in the mud of the estuary of both the large rivers that drain the Miliwood area, the Gowkamma (Homtini) and the Knysna. In both these cases I think it easier to explain the carriage of the precious metal by the solution theory rather than on the gravitation theory, for gold being so heavy tends to remain where it is in the quartz-reefs, and when found in the river-beds it sticks in the hollows and joints of the rocks.

### *The Prince Albert Goldfields.*

The first gold nugget was picked up in the Prince Albert Goldfields in 1871, and twenty years afterwards the fields were proclaimed; they were de-proclaimed in 1898, but since then a good deal of prospecting has been carried on.[1] So far the gold has been only found on the surface; there are innumerable quartz-veins about here, from an inch or so in width to a foot and more, formed of interlocking combs of quartz crystals; the gold is often found in them on the surface, but directly they are sunk upon all traces of gold disappear. The gravels are fairly rich in some places, especially under ledges of sandstone which get loosened on the surface, and some of the nuggets are so fresh that they often exhibit minute octahedra of gold adhering to them with the faces quite bright and unscratched. There are many big saurian bones in the locality which lie about the surface as they weather out of the softer shales, and some of these have also been found to contain crystals of gold in their hollow parts. Mr. H. M. Oakley, who was at one time Inspector of Mines on the fields, informs me that those who used copper pans for washing for the gold very frequently found them coated with mercury after a short while.

So much prospecting had been done on these fields that I was compelled to reluctantly state that the gold must be alluvial, and had been brought from a distance. From a geological point of view this was what I should have expected, as the Karroo shales are too unaltered and too young a formation altogether to carry highly mineralized veins, and the veinstone, also, is so totally different from the usual gold-bearing quartz that no miner would sink on the specimens obtained from the reefs.

[1] An interesting description of these fields, with an account of the general geology, was published by Mr. Sawyer as a Parliamentary Report, G. 45, 1893; the whole question was again discussed by the author, Trans. Phil. Soc. S.A., 1904, xv, pt. 2.

How, then, did the gold get to the locality? The goldfields lie almost midway between the folded mountain range, the Zwartebergen, on the south, and the dolerite-capped escarpment of the great inner plateau on the north. The country is hilly, and the tops of the hills reach a pretty level skyline of about 3,500 feet; on the immediate south there is a wide plain separating it from the mountains. The gold is found equally on the tops of the hills as in the gullies, and there is no higher ground from which it could have been washed anywhere within twenty or thirty miles.

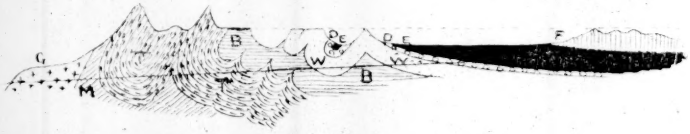



Fig. 2.—Generalized section from the Zwartebergen to the Prince Albert Goldfields, showing the Old High Level Plateau, which has now nearly disappeared.

G, granite; M, Malmesbury Beds; T, Table Mountain Sandstone; B, Bokkeveld Beds; W, Witteberg Beds; D, Dwyka Beds; E, Ecca Beds; F, Beaufort Beds.

A careful piecing together of evidence has shown me, however, that the great river-cut plain that can be seen so plainly in Uniondale and Willowmore must have extended all over this country as well; it was on a level of from 3,500 to 4,000 feet, and stretched northwards from the Zwartebergen to probably the foot of the inland plateau escarpment. Narrow gravel-covered ledges can still be seen on the foot-hills north of the Zwartebergen, and a very much folded range in front of the main chain, composed of hard quartzites of the Witteberg Series, has been cut to a level about 4,000 feet. Far to the north, the hills about the goldfields can be seen cutting a level skyline, and I have been led to consider that there is satisfactory evidence for the former existence of this great high-level plateau, although the traces of it to-day are so scanty. Everywhere where the remnants of the plateau exist, in the foot-hills of the mountains, on the tops of the skirting range, and on the tops of the hills about the goldfields, gold has been discovered. The rivers in those days flowed over this plain northwards, carrying the gold in their waters, whether chemically or mechanically; since then, however, the channels have been diverted, and an easterly-flowing stream has excavated an immense plain at a level of some 1,000 feet below that of the old one, separating the hills about the goldfields from the mountains.

The Zwartebergen are made up of Table Mountain Sandstone, immense quantities of which have been removed in past ages, and a very little gold that may once have existed in the rock became concentrated in the gravels laid down on the old high-level plateau; I conclude, therefore, that the little outlier of the old plateau existing in the Prince Albert Goldfields has derived its gold from the Zwartebergen. I could find no banket beds immediately to the south of the goldfields, but not very far to the east I found a well-

marked bed, which I photographed and reproduced in the paper just referred to.

I was therefore justified in pronouncing against the likelihood of finding quartz-reefs in this neighbourhood, on the grounds that the experience of prospectors was against it, and that from general mineralogical and geological considerations it was impossible to get gold-bearing reefs there.

How, then, can it be explained that the quartz-reefs do contain gold on the surface, sometimes in such quantities that the volume of the gold is far greater than that of the quartz, and the gold nuggets are so fresh, some of them, that crystalline forms are present? It is impossible that the latter can have been rolled any distance.

The theory of solution by ferric sulphate, I think, explains all the facts here as well as in Knysna. The Karroo shales and sandstones contain a considerable quantity of iron pyrites in the form of crystals and thin films colouring the rocks, and it is easy to see how a sulphate could be derived from this salt; where there is lime on the surface the elaboration of a sulphate is very apparent, for the lime becomes gypsum, leaving the iron in the form of red or yellow ochre. Given, then, ferric sulphate and alluvial gold, it is easy to follow the process of the building up of the gold octahedra and nuggets generally.

When it rains most of the water instantly flows away; a little remains and soaks in, absorbing the ferric sulphate and afterwards dissolving a certain amount of gold. This then gets drawn into crevices beneath the sandstones, lodges in hollows in the quartz-reefs where the crystals do not occupy the whole width of the fissure, in the cavernous portions of bones, and finally in the sand on the bottom of the creeks. Here it has ample leisure to corporate during the prolonged droughts, and the crystalline gold is the result. I look to the more frequent application of evaporation to explain the occurrence of gold crystals in the Karroo goldfields; in Knysna, where there is never a real drought, crystals have never been found. Some of the gold nuggets are powdered with red gold, which perhaps is the gold precipitated from solution by the reduction of the ferric salt to the ferrous one, the action being too quick to allow of the coherence of the particles. In the sand the gold has been precipitated in the form of minute spicules.

## REVIEWS.

I.—The Museum Humfredianum, 1779. By C. Davies Sherborn.

ALL interested in Conchology will be glad to know that a copy of this work has at last been discovered in the Hancock Museum, Newcastle-on-Tyne, and the mystery as to whether or not it contained generic and specific names is now finally set at rest. The Catalogue of the Humphrey Museum is of no scientific value whatsoever. I am printing a full description of this rare tract in the *Annals and Magazine of Natural History*, and as the Editor

of the GEOLOGICAL MAGAZINE has suggested that it would be worth while to print here a few entries as an illustration of the matter that interested the scientific, and awed the vulgar, in those days, I have therefore selected and subjoin a few of the items contained in this curious work.[1] The original Catalogue will eventually find a home in the British Museum (Natural History) :—

A very curious specimen of the bark of a tree in coal slate, from Yorkshire.

An exceedingly fine and large Oriental long devil.

A very curious *lusus naturæ* in an English pebble, representing a hen with herbage, and another in a flint, representing a leg and a foot.

Two vice-admirals, and 16 more.

A petrefied nautilus freely exhibiting the concamerations and siphunculus, from Sheepy Island.

A pair of Tower of Babel, exceedingly fine.

A Persian music, and a fine yellow furbelowed oyster.

Part of a very scarce alatus and a curious buccinum, from Hordwell Cliff, and a piece of limestone with pediculi trilobi imbedded in it, Wales.

A large slab of a singular kind of stone, lately discovered in Derbyshire, supposed by some naturalists to be a species of lava.

Part of a large ammonites with ramified chambers, sprinkled with marcasites, from Bath.

A large Swiss breeches, from the East Indies.

A mass of bivalves imbedded in sandstone.

A large mass of bones, with fragments of limestone, in a red calcareous bed, from the rock of Gibraltar.

A crystallized lady and a portrait of Mother Shipton in flint.

Two suns, a staircase, and 6 more.

Two poached eggs, a toad, and 6 others.

Part of the outer twirl of a very large ammonites.

A pediculus in Fuller's earth, rare.

A pediculus marinus extended, and another rolled up, from Dudley.

One valve of a polyleptoginglimos, with curious adhesions of purple furbelowed oysters.

Two shoulders of mutton and two large leopard cowries.

Two lions in shell-work.

A black slate with impression of a lizard, very rare, from Davila's collection.

A skeleton of a fish (a kind of plaice) in an iron stone, from Westmoreland.

A fine Hampstead pebble; a beautiful jasp-achates, Germany; and a rare brown cauk, Derbyshire, all polished.

Two magpies, a devil, a painted cockle, a sun, 2 false Guinea admirals, and 2 Otaheite cowries.

An impression of a flying-fish in yellow slate, Solenhofen, very rare.

Two ass's ears, a devil, 2 figs, 2 blackamoor's lips, and 6 more.

[1] The spelling is after the original work.

An exceedingly fine group of 13 club spines of echini in chalk, Kent, and a fine cast of a cuneous frosted with marcasites and spars, Bath.

An Oriental devil of the first magnitude, very fine.

The body of a species of encrinus, composed of angulated plates, *non descript.* and very rare, from a chalk pit in Surrey.[1]

A most capital petrefied subject, being the thigh-bone of some very large animal,[2] supposed to be either an elephant or hippopotamus, found in a stone quarry at Stonsfield, Oxfordshire.

The skeleton of an alligator, in black slate, extremely rare, Germany.

A most elegant and capital petrefaction of an *Echinus overius*, with about 50 of its spines adhering to it, placed in as nice order as in a recent shell, imbedded in chalk, Kent. This specimen may be truly said to be invaluable, and is undoubtedly unique.

Three small gregories.

## II.—On Lists of Fossils.—Yorkshire Geology.

*The Naturalist.—Actinocamax plenus.*

Mr. Marr, in his presidential address to the Geological Society in February last, made the following excellent remarks:—"It is surprising how many fossil lists of the organisms contained in the strata of our own Island have been drawn up as the result of a few hours', or at most of a few days', work by the collector." And "The rough-and-ready methods which, in some cases, have been pursued in compiling lists of fossils of the different sediments would not be tolerated at the present day in any other branch of science; it is time, indeed, that the stratigraphical geologist should apply himself to his own branch of work with the assiduity and attention to detail which are now expected of the palæontologist in the Museum." These words should be written in letters of gold across the study-wall of every field geologist.

Yorkshire men, however, care for none of these strictures, for their diligence in the search for fossils is well known. That it was greatly stimulated by the visits of Dr. Rowe to the Yorkshire Chalk was obvious, and one of the chief results is seen in the July number of *The Naturalist*, where Mr. C. Thompson describes the first discovery of *Actinocamax plenus* in the 'Black Band' and overlying a few inches of marl in Yorkshire. Repeated and continuous search has at last been rewarded, for altogether three specimens are recorded, one of which was found by Dr. Walton. This characteristic zonal fossil is fairly common south of the Humber, but up to the present discovery not a single specimen has been found north of that river. As Belemnites are 'spotty' things, and from their shape roll about and get into depressions of the sea-floor, it is quite likely that it may be some time again before another lot is found.

The July number of *The Naturalist* is of considerable geological

[1] Very interesting in view of the recent 'discovery' of *Marsupites* in Surrey.

[2] Probably *Megalosaurus*.

interest, for, besides the above note, there are papers by Kendall on the concealed coalfields of Yorkshire, Derbyshire, and Nottinghamshire; C. Johns, Geological Notes on Askrigge; Stather, on the Geology of Louth; and Brown, on *Janassa bituminosa* from the Marl Slate, Thickley. The number is excellently illustrated, and the journal well deserves the place it holds as a record of the Natural History of the North of England.

## REPORTS AND PROCEEDINGS.

### Geological Society of London.

June 21st, 1905.—J. E. Marr, Sc.D., F.R.S., President, in the Chair. The following communications were read:—

1. "The Relations of the Eocene and Cretaceous Rocks in the Esna-Aswan Reach of the Nile Valley." By Hugh John Llewellyn Beadnell, F.G.S., of the Geological Survey of Egypt.

At the meeting of the International Geological Congress held in Paris in 1900, the author brought forward evidence from the Baharia Oasis and Abu Roash to show that there was a marked unconformity between these two systems in the northern part of the country. The Jebel-Awaina succession shows that in the southern part of the country, where the Upper Cretaceous and the Lower Eocene occur in their fullest development, there is no sharp line of demarcation between the Cretaceous and the Tertiary, and no disturbances in the stratigraphical succession. This is confirmed by the succession in the Kharga Oasis, where there is no trace of an unconformity. Dr. J. Ball's conclusions to the contrary were mainly based on the supposed irregular variation of the Esna Shales; but where this occurs it is mainly due to the fact that, with a slight increase of carbonate of lime, these beds became almost indistinguishable from the overlying marls and marly limestones of the Eocene. The author finds in Jebel Nur el Ghenneiem some 180 feet of green clays between the *Echinocorys* Chalk and the Eocene marls and limestones, and a perfectly conformable succession throughout. Near Ain Amur there is a considerable development of fossiliferous limestones at the summit of the Cretaceous rocks, and many of the fossils are hardly distinguishable from Eocene species. The author is of opinion that the Farafra succession falls into line with that which obtains in the southern part of the country. An important piece of confirmatory evidence is furnished by the discovery of a rich fauna in 'ashen-grey clays' in the Esna-Aswan Reach of the Nile Valley by Dr. W. F. Hume, in the clays above the *Pecten* Marls in the neighbourhood of Esna.

2. "A Contribution to the Study of the Glacial (Dwyka) Conglomerate in the Transvaal." By Edward T. Mellor, B.Sc., F.G.S. (Communicated by permission of the Director of the Geological Survey of the Transvaal.)

The survey of a district lying east of Pretoria and extending

from near the Diamond Fields to Middelburg, has recently afforded much additional information with regard to the Glacial Conglomerate in this part of South Africa. The district lies on the northern edge of the principal area occupied by the Karroo System, and includes a number of outliers, the area between which affords information as to the source of the material of the Conglomerate and the character of the land-surface on which it was deposited. This surface is smoothed, grooved, and scratched by ice-action. The Karroo System is here only 400 or 500 feet thick, and the Conglomerate usually about 50 feet; but, where deposited in hollows, it may reach 200 feet or more in thickness. The fragments are usually from 1 to 3 feet in diameter, but may attain as much as 8 or 10 feet; they are often facetted and sometimes show striations. The majority of the boulders are of local origin. True bedding-planes are rare in the Conglomerate, but there are included patches of sandstone, mudstone, or shale, some of which show ripple- or eddy-markings. The striæ are remarkably constant in direction, and they and the transport of boulders indicate an ice-movement from the north-north-west to the south-south-east. In the Prieska district Rogers and Schwarz found the movement to have been from north-north-east to south-south-west, and the same direction is given by Schenck from near the junction of the Orange and Vaal Rivers. During 1904 outliers of the Conglomerate were found farther north, near the junction of the Elands and Olifants Rivers.

3. "On New Oolitic Strata in Oxfordshire." By Edwin A. Walford, F.G.S.

The divisions of the Inferior Oolite of North-West Oxfordshire are described, and a quarry on the border of the county cited where the Cotteswold facies dies out in the '*Parkinsoni*'-stage. A higher division of the same stage (the *Trigonia signata* beds) of Northamptonshire type is shown to sweep over the North-Eastern Cotteswold region. The siliceo-calcareous beds (Chipping Norton Limestone) cover the countryside which gives them their name, and are about 30 feet thick. Fossiliferous strata, separated from the Chipping Norton Limestone by a bed with vertical markings and a black clay-band, indicative of much 'inter-waste' of these and other beds, are described. They are shown to be similar to the Lincolnshire (Ponton) strata described by Morris, Judd, and Woodward. A new term is proposed for these beds, which are characterized by the presence of the shell *Neæra*, from the *Perna* Marls above the black clays to a higher series of black and green clays underlying the Stonesfield Slate. These beds and the Chipping Norton Limestones are classed with the sub-Bathonian. The beds equivalent to those of Oxfordshire have, in Lincolnshire and Northamptonshire, been known in part as Upper Estuarine. In the 20 feet of Oxfordshire strata there appears to be represented the 150 feet of the Lincolnshire Limestone and the Upper Estuarine of the north-eastern counties. The author expresses the hope that his work may help towards the discrimination of the two kinds of deposit known as Lincolnshire Limestones, inasmuch as the fossils

characterizing each local (Oxfordshire) stratum have been collected from the beds *in sitâ*. Lists of fossils are given.

4. "The Causes of Variegation in Keuper Marl and in other Calcareous Rocks." By Gerald Tattersall Moody, D.Sc., F.C.S. (Communicated by Professor W. W. Watts, M.A., F.R.S., Sec.G.S.)

Analyses of a large number of specimens of Keuper Marl bring to light the fact that the red portion of a variegated rock contains a considerably higher percentage of iron and lower percentages of calcium-carbonate and magnesium-carbonate than the green portion. This is in agreement with earlier observations that red strata are usually less calcareous than adjacent green strata; but the author is unable to confirm the hypothesis advanced by Maw,[1] that the lighter-coloured bands in variegated rocks are produced by bleaching or discoloration of red rocks through addition from extraneous sources of lime and magnesia. On the contrary, it is found that the removal of iron existing as ferric oxide from a homogeneous rock-mass is inhibited if calcium-carbonate, or magnesium-carbonate, or both of these substances be present. When, however, a chalybeate water (ferrous bicarbonate solution) permeates a rock containing magnesium-carbonate or calcium-carbonate, iron is precipitated as ferrous carbonate, and an equivalent weight of magnesium or calcium passes into solution. Subsequent access of air oxidizes the ferrous carbonate, and red or yellow ferric oxide is produced. The author finds that when a green marl is subjected to the action of chalybeate water in the manner indicated, it is readily converted into a material closely approximating, both in appearance and in composition, to the natural red marl of the same rock-mass.

The author concludes that the variegation of the Keuper Marls and of other calcareous rocks has been brought about by the percolation of chalybeate water through the light-coloured mass, the more porous parts of which have in consequence become stained with ferric oxide, while the harder and more crystalline parts, being non-porous, have remained unchanged. The uniformity in distribution of ferric oxide in some red rocks, such as the New Red Sandstone, suggests that the iron contained in them has probably been derived from chalybeate water in a similar manner.

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The next Meeting of the Society will be held on Wednesday, November 8th, 1905.

## CORRESPONDENCE.

### WHERE ARE THE TYPES?

Sir,—May I ask if any of your readers can kindly give me the information as to where may be found the types of S. P. Pratt (Kelloway Ammonites from Christian Malford) and of Young & Bird (Lias Fossils in "Geology of Yorkshire")? The information is required for the purposes of the *Palæontologia Universalis*.

Westfield, Thame, Oxon. S. S. Buckman.

[1] Quart. Journ. Geol. Soc., vol. xxiv (1868), pp. 35 et seqq.